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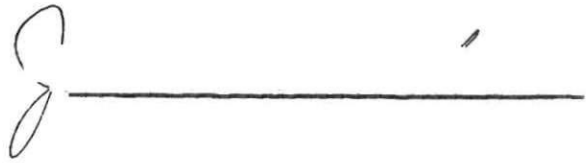

THE EFFECT OF SIZE AND SHAPE OF EQUIPMENT DIALS AND KNOBS ON WORKER PERFORMANCE

A THESIS

Presented to

the Faculty of the Graduate Division

by

Jesse Harrell Oswalt

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Industrial Engineering

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March, 1961

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Date Approved by Chairman: 4-19-61

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Without the assistance and encouragement of the many people who were involved, the successful completion of this study would have been impossible. I wish to express my appreciation to all members of the thesis committee. I would especially like to thank Dr. David C. Ekey for his help in selecting an area for study and for his guidance and encouragement in the performance of the investigation. Dr. J. J. Moder, Jr. gave very valuable assistance in the statistical analysis of results.

There are many faculty members and students at Mississippi State University for whose assistance I am very grateful. Mr. A. G. Holmes, Head, Department of Mechanical and Industrial Engineering, gave valuable aid and encouragement during the construction of the equipment used in the study, and during the actual research.

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ABSTRACT

The purpose of the investigation was to evaluate operator preferences related to the control of three dials by three "stacked" control knobs mounted on a single axis. One question was whether or not subjects would choose a dial-knob association according to shape or size rather than a stereotype of association. The effect of a "staggered" horizontal array of dials on choice of association was investigated. The preference of dial-knob association, for arrays of dials in the form of a "V" and inverted "V", was studied. The last phase of the study was conducted to determine the diameters of a stacked knob arrangement for which optimum accuracy could be attained.

All controls and dials for the determination of preferences were simulated. The dials, with preferred design characteristics, were aligned horizontally in the shape related phase, size related phase, and the "staggered" dial phase. One hundred subjects' preferences were recorded for each of the six possible combinations of dial arrays for both the shape related and size related phases. Fifty subjects' preferences were recorded for each of the three control knob positions of the "staggered" panel phase. The preferences of association of dial and knob for one hundred subjects were used to develop the stereotype of a "V" array of dials when the stacked controls were located just below the lower dial. A like number of preferences was measured for the inverted "V" dial array, with the control knobs located mid-way between the two lower dials.

For the phase concerned with accuracy, nine stacked knob-diameter arrangements were used. Knob diameters varied between one quarter inch for the front knob position to three inches for the back knob position, while length was held constant at one inch. Five operators attempted to make prescribed dial settings, using the three stacked knobs. The time allowed for a setting was constant for each of the three knob positions and was controlled by an electrical timer and a braking mechanism attached to the linkage between dial and knob. The distance of pointer travel was constant for all trials. Two replications of trials were obtained.

Shape and size were found to be the primary influencing factors used for association of dial and knob. These associations were predominant over the established stereotype of association of front knob-left dial, middle knob-middle dial, and back knob-right dial. For the "staggered" dial array, the established stereotype of association was found to be predominant. The preferences for the "V" dial array formed a counter-clockwise association of dials going from front to back on the stacked knobs. The preferences for the inverted "V" array proved to be a clockwise association of dials going from front to back knob. All associations were significant at the 0.1 per cent level. The results of contingency tables showed non-independence between tests as related to shape and to size at the 0.1 per cent significance level.

There were no significant differences between the largest number of choices for the test results related to shape and to size and when both associations were combined. The second highest number of choices between tests of choice related to shape and size combined proved significant at the five per cent level. These choices between tests were ranked.

The amount of confusion as to the number of choices among subjects proved to be significant at the 0.1 per cent level. This was true in the shape and size related phases and also when these results were combined. There were no significant indications of confusion on the staggered panel array. The conclusion was drawn that two or more means of association should be used when possible.

An analysis of variance was performed to determine which variables had significant effects on the accuracy of dial settings in the fifth phase. Size and replication were considered fixed variables and operator was considered to be a random variable. All sums of squares for the interaction terms were pooled with the residual to get an estimate of the error. Size effect was found significant at the one per cent level. Further analysis showed the difference in results for the smallest size knob arrangement to be significant from the results of seven larger size arrangements. The significance level was one per cent. The linear component of size effect was not significant.

CHAPTER I

INTRODUCTION

Traditionally, time and motion studies have always been concerned with the working arrangements between men and machines. Recently, however, more intensive research has been done on these man-machine relationships to try to determine the best possible performance conditions.

That this kind of research is important is clear from investigations conducted in the Armed Forces, especially by the Air Force. There, for example, the necessity is extreme that a pilot be able to distinguish controls and dials as rapidly and accurately as possible. An error could cost him his life and the country an expensive and needed aircraft. The location of the controls he must work with, and the adjustments he must make on them, therefore, are critical. Error must be reduced and, if possible, eliminated.

The same point is valid for industry. With the increase in automation of all kinds of equipment, location of controls is important in terms of operator energy, and thus the safety and economy of the entire process. There are many kinds of equipment which could be operated more efficiently if multiple dials could be controlled by stacked knobs.

The present investigation, therefore, is a part of current research into this problem of location, size, and shape of controls. Specifically it was aimed at finding out what relationships machine operators prefer between knobs ganged or stacked on a single axis, and the dials these knobs

control. The investigative method was similar to that used in previous studies on the same general subject. Design characteristics found to be most effective by other investigators were incorporated into the dials and control knobs used. Test equipment was devised and college students recruited to serve as subjects or operators. Their reactions were observed and recorded and the results tabulated according to established statistical methods.

The relationships these "operators" were asked to choose among were determined in advance and are here discussed as five phases.

Phase One. The Control-Dial Association Preference of Ganged Controls as Related to Shape.-- In studies conducted by Bradley (1) at the Aero Medical Laboratory, there were found to be very strong subject associations of front knob to left dial, middle knob to middle dial, and back knob to right dial, especially when the dials were aligned in a horizontal array (predominate stereotype). The relation of dial shape to choice of control was studied, but only different dial shapes were used. The control knob shapes remained round in all phases of the study.

The intent in Phase One of this study was to determine which associations were stronger in subjects: the association of shape of dial to shape of control or the prevalent stereotyped association of front knob to left dial, middle knob to middle dial, and back knob to the right dial. Three different shapes of dials and similar shapes of stacked control knobs were used (see fig. 1).

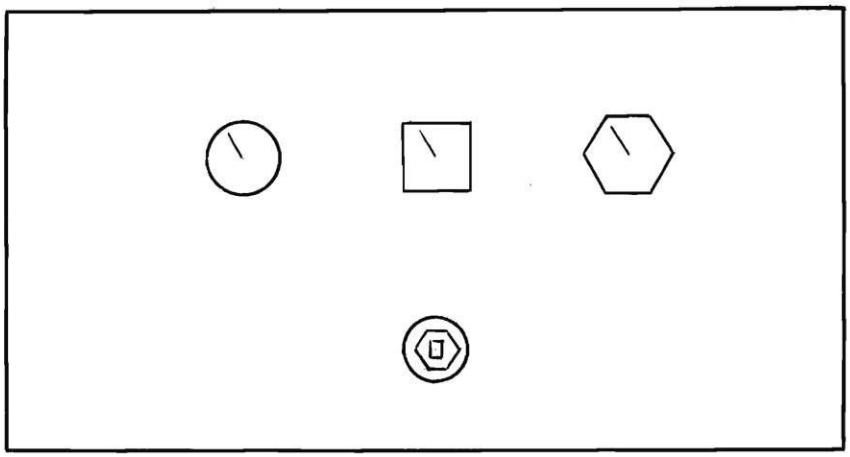


Fig. 1. Sketch of Dial and Knob Shape for Phase One

Phase Two. The Control-Dial Association Preferences Ganged Controls as Related to Size.-- In Bradley's investigation (2), mentioned previously, further tests were conducted to determine the relation of dial size to choice of control knob. One association was found to be significant among the subjects: that is the association of front knob to smallest dial, middle knob to medium sized dial, and back knob to largest dial. He arranged his semi-circular dials in the "northwest", "northeast", and "southwest" positions relative to the constant size control knobs which were "stacked" (see fig. 2).

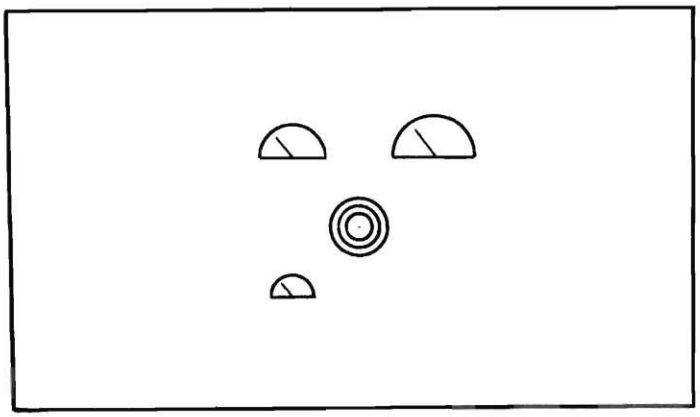


Fig. 2. Bradley's Dial Array as Related to Size

It was the intent in Phase Two to determine which associations were stronger: the developed stereotyped association of front knob to left dial, middle knob to middle dial, and back knob to right dial or the size associations. The dials were circular, aligned in a horizontal array above the controls, and of different sizes, while the control knobs were "stacked" (see fig. 3).

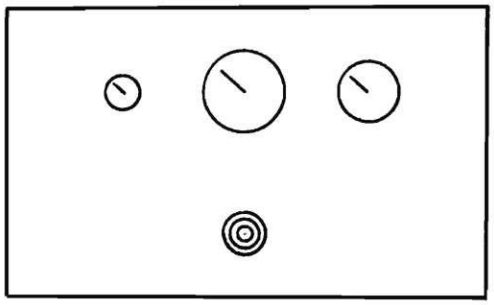


Fig. 3. Sketch of Dials and Controls for Size Related Phase Two

Phase Three. The Control-Dial Association Preferences of Ganged Controls as Related to Staggered Dials.-- This phase of the investigation was made to find what knob and dial association would be preferred by operators when dials were staggered and knobs were stacked. The dials were located on panels which were "stepped" or "staggered" in depth from the subject. Three dials were aligned horizontally and the controls were placed on one of the three panels (see fig. 4). Subject preference of association was then analyzed as the controls were changed to the three panel positions.

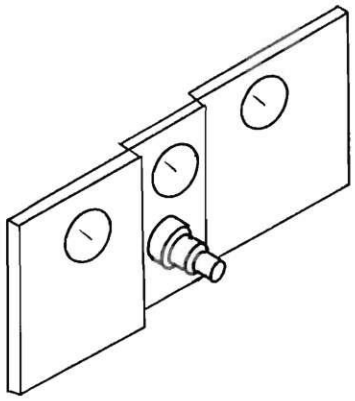


Fig. 4. Sketch of Staggered Panels with Controls and Dials for Phase Three

Phase Four. The Control-Dial Association Preferences of Ganged Controls as Related to "V" Array and Inverted "V" Array.-- Most of the arrays which have been investigated in other studies (by Bradley, for example) had dials in a horizontal array, a vertical array, or in the "northeast", "northwest", and "southwest" array. In Phase Four of the present study, the control-dial associations of two other arrays were studied. In one of these arrays (see fig. 5), a "V" array of dials was made with the controls placed just below the lower dial position of the "V". In another (see fig. 6), an inverted "V" of dials was arranged with the stacked controls in line and between the two lower dials.

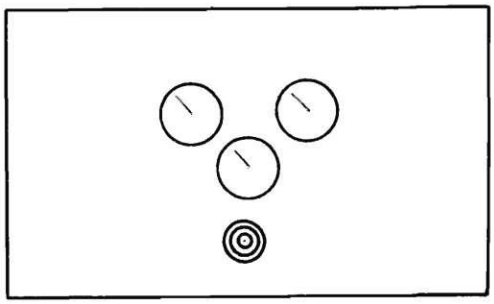


Fig. 5. Sketch of Controls and Dials for "V" Array of Phase Four

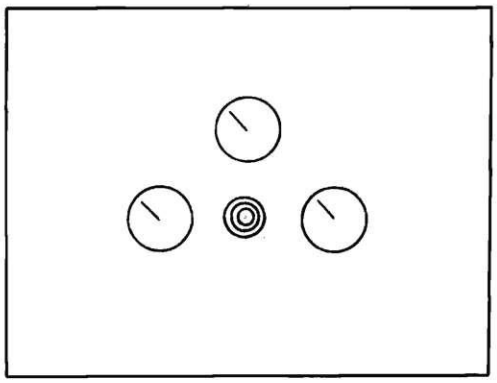


Fig. 6. Sketch of Controls and Dials for Inverted "V" Array of Phase Four

Phase Five. The Evaluation of the Optimum Accuracy for Stacked Control Knobs of Varying Diameters.-- This phase of the investigation was intended to determine if there were optimum diameters of control knobs, arranged in stacks which would affect operator's accuracy. The lengths of the knobs were held constant while their diameters were varied simultaneously.

A research of available literature on the subject of knob-dial relationships shows that no similar study has been conducted. Jenkins and Connor (3) used different sizes of a single control knob to control a pointer on one linear display. The one knob was moved to control a pointer in an effort to make a prescribed setting on the linear scale.

Expected Results.-- A null hypothesis of independence of choice was advanced for the first four phases of the investigation. This null hypothesis assumes that all associations relating dial shapes and positions to control knobs occur equally often in the population of workers. Rejection of the null hypothesis was expected.

In Phase One, dial and knob shapes were expected to produce opera-

tor bias, i.e., shape would be used by the subject as the principal means of associating dial with knob. In Phase Two, size was expected to be a significant factor. The developed stereotyped association of front knob to left dial, etc., had appeared significant in previous studies with semi-circular dials, round knobs, and a single display plane (4). It was hypothesized that the operators would have an even greater bias of knob-dial choice when staggered panels were used, as in the third phase of this study.

The fourth phase of the study concerned variables which had apparently not been investigated previously. It was expected, however, that some association between dials and knob arrangements would prove predominant.

For the first two phases of the study, another hypothesis was that significant differences in number of subject choices would be found among the six different arrangements of dials possible within each phase. Wide variation was expected in the largest number of choices for various trials within a given phase. In some arrays presented, the primary stereotyped association of front knob to left dial, etc., was working in conjunction with shape and size. In other arrays, the secondary stereotyped association of front to right dial, etc., was working in conjunction with the new associations. However, in four of the six arrays presented to the operators, choices could not be influenced by primary or secondary associations. The above hypothesis would also apply to the number of choices between different positions of the control knobs in the third phase. It was thought that some one section of the panel would produce more conclusive results than the other two sections; that is, the first or largest

choice of one section would be significantly larger than the other sections.

Although a null hypothesis of independence of choice was offered for the first four phases, a hypothesis was made that certain combinations of dials and knobs would be preferred by some of the operators. This variability of choice, i.e., lack of complete agreement among subjects, was considered as a degree of "confusion" in the manner of associating dials and control knobs.

For the fifth phase, it was hypothesized that some one design of knob diameters could be found which was better than any other design.

CHAPTER II

INSTRUMENTATION AND EQUIPMENT

For Phase One through Phase Four, the controls and dials were simulated; that is, there were no linkages from controls to the dials and the pointers on the dials were drawn on the dial face. The control panels were constructed from one-eighth inch plyboard. Above the three dials, from left to right, were the arabic numerals one, two, and three (see fig. 17). Some bias may have been introduced into the research by this numbering system, but no more so than if the verbal instructions had included directions for the subject to choose a control knob for the dial on the left, for the middle dial, or for the right dial.

The round dial of Phase One, the largest dial of Phase Two and the dials used in all other phases were two and eight-tenths inches in diameter. This dial size had been used in previous studies and found to be satisfactory (5). The dial was graduated in tenths for the primary or unit marker. Four equal intervals were placed inside each of the primary units, thus graduating and placing markers on each one-fourth unit. The markers were 25 thousandths of an inch wide and the primary or unit marker was three-sixteenths of an inch high. The half unit markers were one-eighth inch high and the quarter unit markers were one-sixteenth inch. The numerals on these dials were similar to those shown to be preferred in the Aeronautical Medical Equipment Proposed Numeral Form (6) and were placed on the dials with a Leroy lettering set. They were one-half inch high and had a height to width ratio of four to three. The numerals were

placed on the outside of the dial enclosure in accordance with preferred design criteria (7). The pointer was one-eighth inch in width and one and seven-eighths inches long. The pointer came to a distinct point and was so positioned that the tip of the point coincided with the inside point of the one-fourth unit marker. The background for the dials used for Phases One and Two was white and the numerals, etc., were applied with black india ink. For Phases Three through Five, the dials were drawn as black on white and by use of a photographic process, were printed white on a black background. Thus, they were like the dials used on aircraft and on studies connected with numerals and letters (8).

Phases One and Two.-- The control knobs for Phase One were arranged as shown in Figure 7 and were made of steel. All dial features except size and shape were the same as those contained in the round dial. The square dial was two and eight-tenths inches per side of the square. The hexagonal dial was designed so there were two and eight-tenths inches between opposite sides.

For Phase Two, the dial diameters of two and eight-tenths inches and one and four-tenths inches had been used in previous studies (9). These two diameters were used in the present study with a third one which fell at the mid-point. The control knob sizes are shown in Figure 8 and were the same as those used for Phases Three and Four.

The distance between centers of the dials was five inches and the axis for the control knobs was located directly below and at a distance of seven inches from the mid-point of the middle dial. The panels, painted white, were seventeen inches high and twenty-seven inches wide.

To facilitate quick change of the differently shaped and sized dials

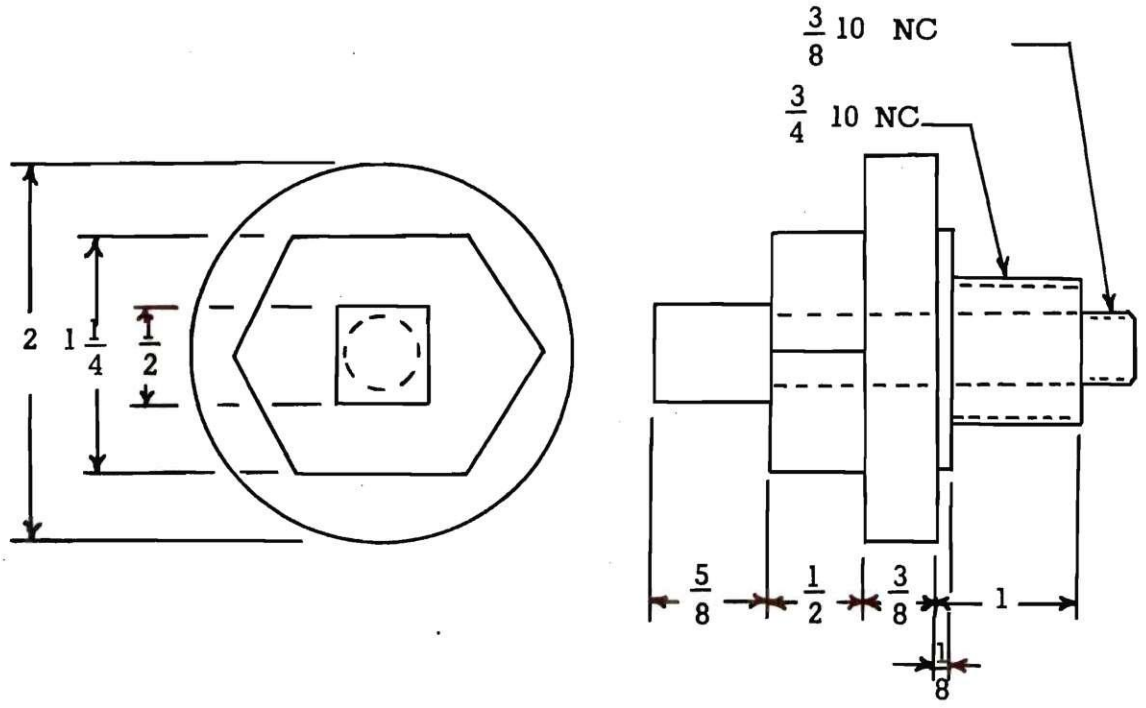
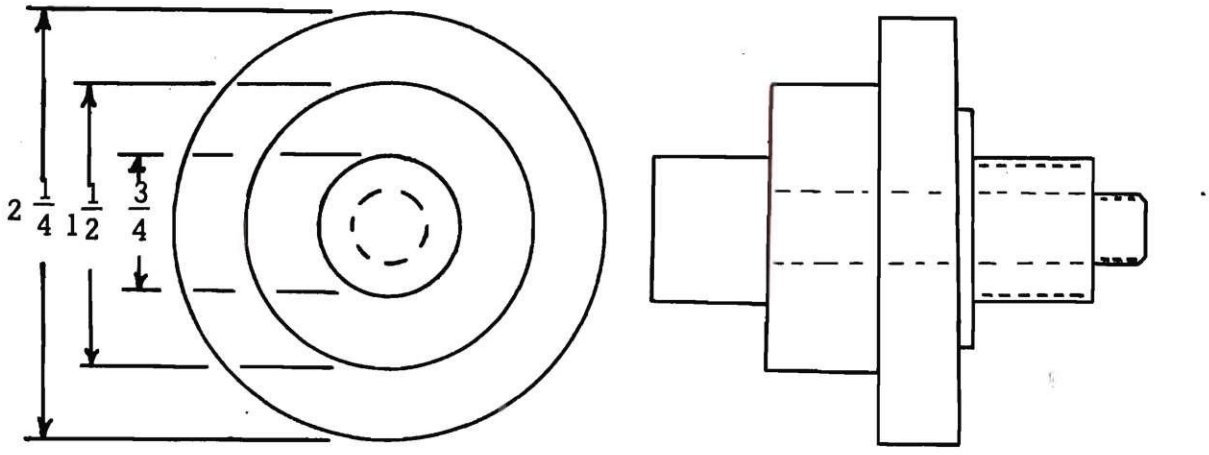


Figure 7. Control Knobs and Bushing Used for Study Where Shape of Knob was Related to Shape of Dial.



See Dimensions Figure 1

Figure 8. Control Knobs and Bushing Used for Size Related Phase Staggered Panel, and "V" Arrays.

from one position to another, metal holders were provided. The holders were of correct size and shape to hold a four inch square cutout of the dial and were fabricated from brass strip stock. The brass thickness was such that it could easily be formed to shape on a hand brake to provide minimum frame exposure.

Phase Three.-- The panel, painted black, was cut into three sections and assembled so that the middle section was one-eighth inch back from the face of the left section, and the right section was one-eighth inch further back (see fig. 9).

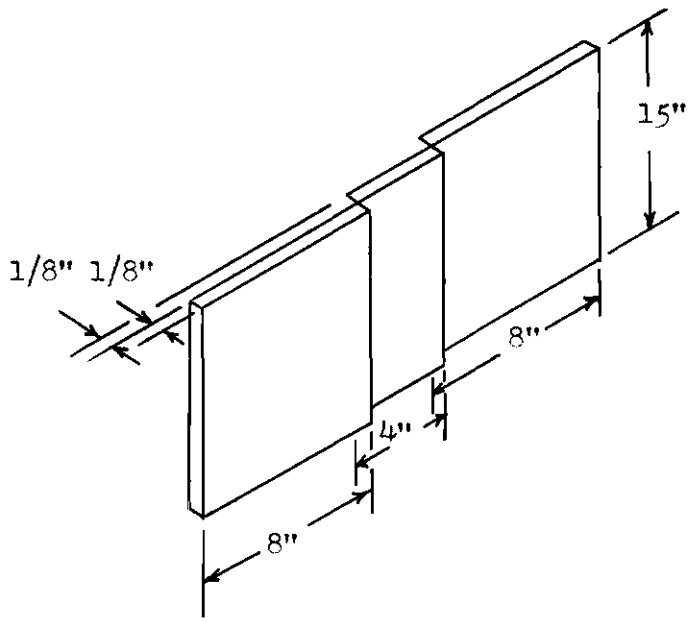


Fig. 9. Sketch of Construction Details of Panel for Phase Three

One three-fourths inch hole was drilled and counterbored in each of the three panels so that when a certain number of subjects had made their choice at one position, the control knobs could be easily changed to another position.

Phase Four.-- The panel was again painted black and was twenty-two inches

wide and seventeen inches high. This phase was divided into two parts. In one part, the dials were placed in a "V" array with the control knobs located four inches from the lower dial (see fig. 10). The upper two dials were located on lines 45 degrees from the line passing from the control knob axis and the center of the lower dial.

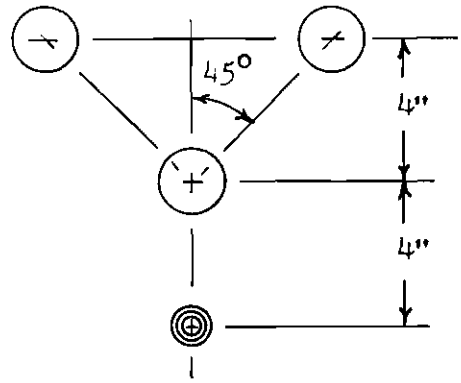


Fig. 10. Sketch of Construction Details for "V" Array of Phase Four

In the other part of the phase, the same control knob shaft was used and the panel reversed and inverted. The dials were attached to the panel to form the shape of an inverted "V". The distance between centers of the lower two dials was eight inches. The control knob axis was located at mid-point of a line between centers of the lower two dials (see fig. 11).

Phase Five.-- The panel was constructed from three-fourths inch plyboard and was three feet wide and two feet high. The dials were mounted horizontally with a distance of six and one-fourth inches between centers. The pointers were drawn on regulation drawing paper and then attached to 0.020 inch steel shim stock which was shaped to the same dimensions as the drawing.

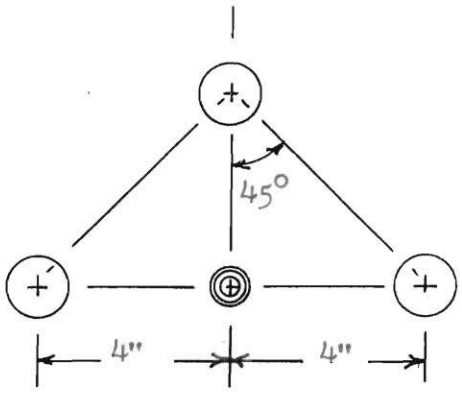


Fig. 11. Sketch of Construction Details for Inverted "V" Array for Phase Four

The control knobs were mounted one foot below the center line of the dials and directly below the middle dial. The knobs were again stacked on a single axis and were attached to concentric protruding shafts. Pulleys, one and one-half inch in outside diameters, were attached to the opposite ends of the control shafts, after the shafts had been mounted on the panel (see fig. 12). Twelve steel knobs, each one inch long, were required for the complete series of trials (see table 1).

Friction was not considered to be detrimental in the research, as the time allowed for each setting and the distance of pointer travel were constant. Jenkins, Maas, and Rigler (10) found that the optimal pointer movement to knob rotation ratio, with respect to speed and accuracy, was unchanged for short travel distances of the pointer and only slightly increased for large amounts of pointer travel. This was true when the amount of friction was varied.

Jenkins and Connor (11) found the optimum ratio to be 1.18, expressed in inches of pointer movement for one complete turn of the knob. This was tested for a single control knob moving a pointer on a linear scale.

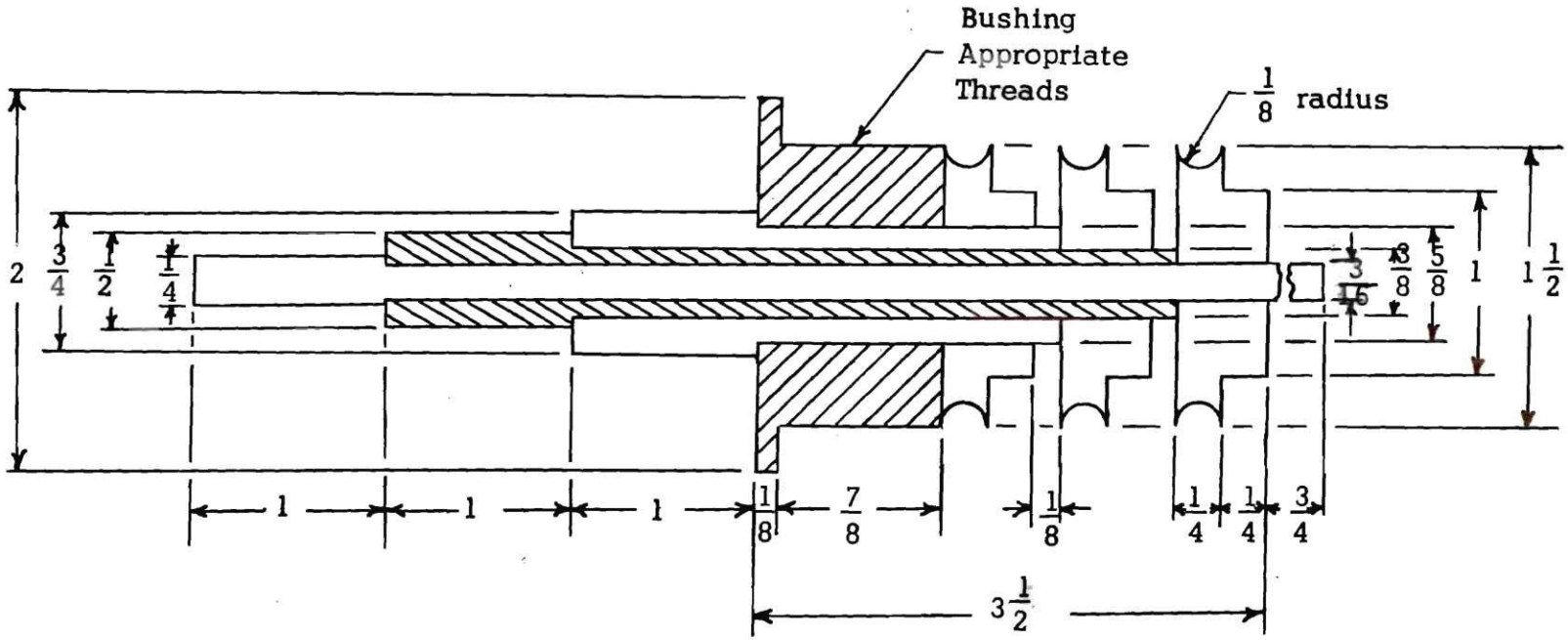


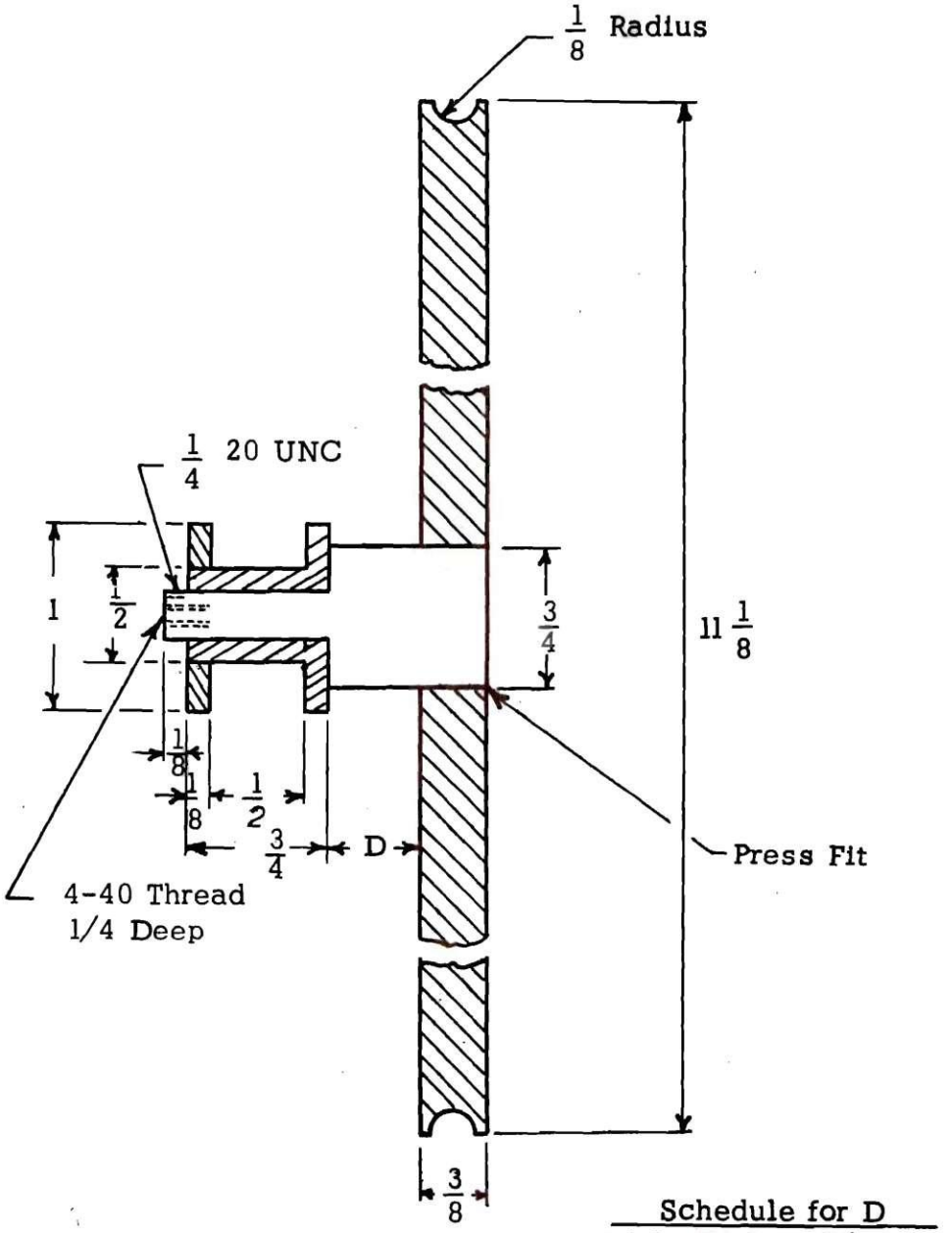
Fig. 12. Control Shafts and Pulley Arrangement for Phase Five

For this reason, pointer movement in the present study was designed for similar action around the circumference of the dials. This pointer movement required that the pulley, attached to the shaft rotating the pointer, be 11 1/8 inches in diameter. The shafts for the pointers were of different lengths and the pulleys were overlapped to prevent the dials from having to be located approximately two feet apart (see fig. 13). The upper pulleys were made from three-eighths inch aluminum plate. Jenkins, Maas, and Olson (12) found that added inertia had little or no practical effect on performance when making settings on a linear scale. Therefore, the relatively large moment of inertia of the pulley and shaft for the pointer was not considered detrimental in this study.

Table 1. Schedule of Control Knob Sizes for Phase Five

Item	Outside Diameter Inches	Inside Diameter Inches
1	1/2	1/4
2	3/4	1/2
3	1	3/4
4	3/4	1/4
5	1 1/4	3/4
6	1 1/2	3/4
7	1 3/4	3/4
8	2	3/4
9	2 1/4	1/2
10	2 1/2	3/4
11	2 3/4	3/4
12	3	3/4

Round leather belts of three sixteenths inch diameter were used for the connecting linkage between the pulleys on the control shafts and those on the pointer shafts. The belt tension was maintained by



Schedule for D	
Right Dial	3/16
Middle Dial	1 3/16
Left Dial	1 7/16

Fig. 13. Shaft and Pulley Arrangement for Pointer Used For Phase Five.

springs of appropriate size which were attached between the ends of the belt. Belt slippage, when the brake mechanism was released, was prevented by the application of belt dressing.

Three solenoids, Model GE 22D128-G2, served as brakes. A "T" shaped piece of hard rubber was attached to one end of the solenoid brake core. The solenoid was mounted with a spring inside the coil windings and against the opposite end of the core. The mounting brackets for the solenoids had elongated slots so that the proper distance and spring tension could be obtained. The "T" rubber pad was mounted against the upper pulley to serve as the brake pad.

Time of operation was controlled by an electrical Model No. 1 Repeat Cycle Timer. Timer outlets one and two (of six) were used for the circuits associated with the left and right dials. Outlets two and three were used for the circuit associated with the middle dial. The time of electrical contact between common timer outlet two and outlets one and three could be varied by controls on the face of the timer. A two-way Leach Relay completed the circuit for the left dial. A Metered Variac was used to remove power after the prescribed settings had been attempted. Thus, some of the heat was dissipated from the coils of the solenoids and uniformity of operation was provided. The schematic wiring diagram is shown in fig. 14.

Three 115 volt panel lamp holders were mounted in front of the panel with one lamp located below each dial. The lenses were red. The mounting panel for these signal lamp holders was made from 0.025 inch thick brass strip stock formed on a hand brake. This panel was two inches high, fifteen inches long, and one and one-half inches deep. One-fourth

inch flanges allowed the signal panel to be attached to the main panel with wood screws. It was mounted five and one-fourth inches below the center line of the dials (see fig. 20).

Jenkins and Connor (13) had used an error tolerance of 0.007 inch with a pointer width of 0.025 inch. This error tolerance was used in conjunction with the 0.025 inch wide marker interval of the present study. To determine if the dial settings were in the prescribed limits, appropriately marked and calibrated dials were placed on the rear of the panel. The dials on the rear of the panel were four and one-half times larger than the smaller dials and were used by the investigator as a rapid means to check the settings made by the subjects.

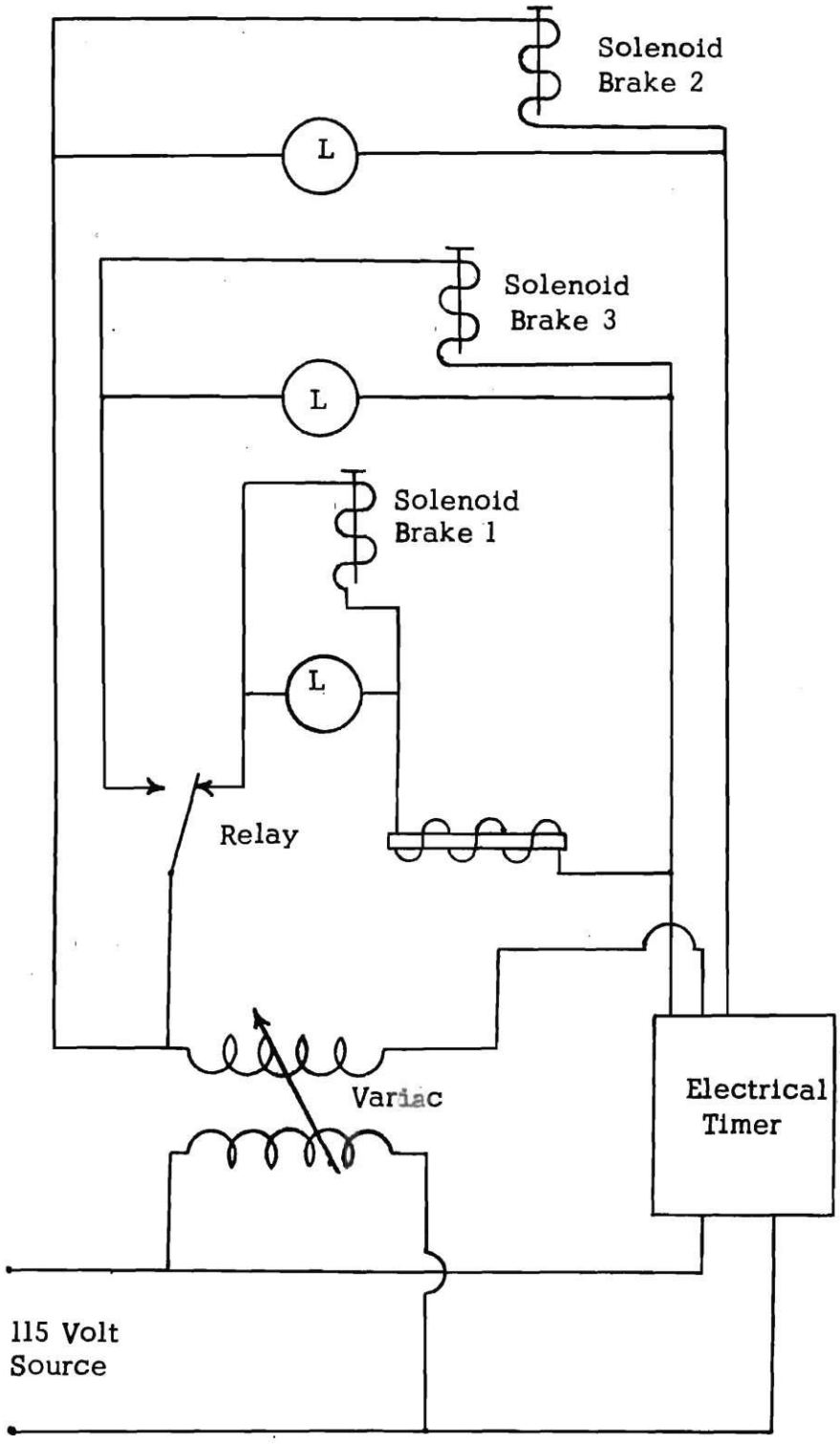


Fig. 14. Schematic Wiring Diagram for Electrical Apparatus. Phase Five.

CHAPTER III

PROCEDURE

The research behind this thesis was conducted in Patterson Laboratories at Mississippi State University during the Spring Semester of 1960. A cooperative research atmosphere prevailed, with all personnel lending assistance whenever possible (e.g., machine shop employees, student subjects, and professional colleagues).

The fluorescent lighting in the laboratory yielded an average intensity of 30 foot candles at operator work level. The noise level was very low, so that the research noise environment was not the same as that in an ordinary manufacturing plant.

Subjects.-- A total of 155 subjects was required for the five phases of the study. These subjects were male college students of the sophomore, junior, and senior classes. Twenty of these students were in Industrial Management and the remainder in engineering. The students volunteered for the research and the interest was abnormally high because of their desire to learn and also because of their interest in experimental procedures. Though the mental ability of the subjects was higher than that which would normally be found in persons working in a laboring position in a manufacturing organization, they were not selected because of any special talents which they may have possessed. Financial remuneration was offered to only the five students taking part in phase five of the study, and only two accepted pay as they were part-time student workers

in the laboratory.

Approach: Phase One--Phase Four.-- Each of the first 100 subjects was required to make three choices from a total of 15 dial-knob associations being sought. The entire associational sequence was performed in a random manner: the order for presentation of dial knob arrays was selected with the aid of Tippett's Random Sampling Numbers (14) in the order shown in fig. 15; random numbers were also used for the "ask" order for each of the 15 arrays presented.

Care was exercised so that no undue bias would be introduced to the subject from anyone associated with the research. Only three experimenters and the subject making the choices were allowed in the section of the laboratory where the choices were being recorded. The purpose of this restriction was so that one subject's choice would in no way influence the choice of another subject.

Printed instructions were prepared and presented to the subjects as they entered the particular research area for the purpose of choosing the dial-knob associations. These instructions were as follows (15):

> This test is conducted to determine choice, only.
> You will be shown simulated dials with simulated stacked control knobs.
> You are requested to make a choice of the knob to use to control the dial specifically asked for.
> Please touch only the control which you would use to make a change in the setting of the dial.
> Please do not discuss your reactions with other possible subjects.

Clarifying verbal information was given only if the subject did not understand what he was required to do. The dial numbers were called in the predetermined sequence and the subject made his choice. Since any one knob could be associated with only one dial, only two dial numbers

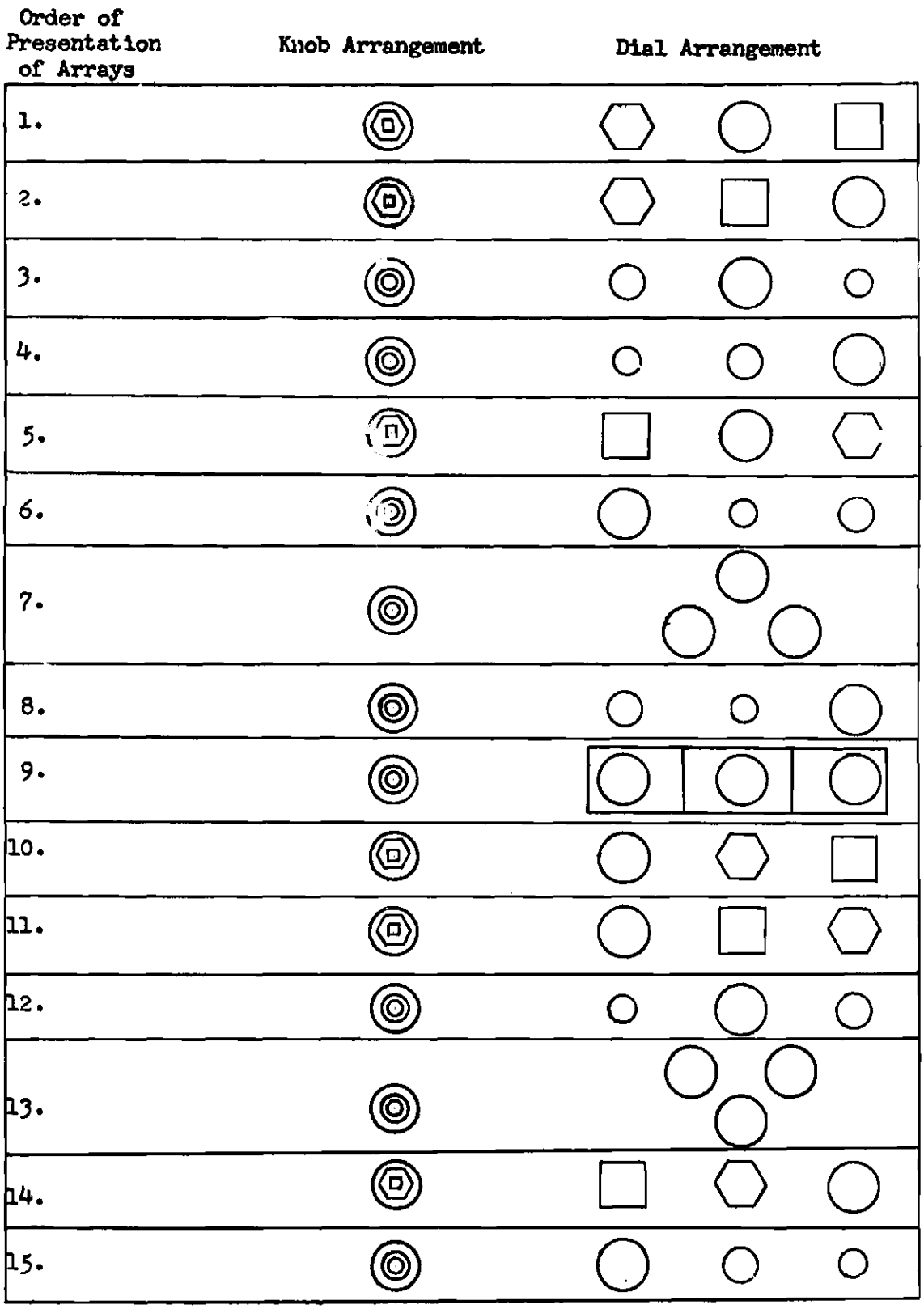


Fig. 15. Fifteen Combinations of Dial and Knob Arrangements Used in Phases One Through Four.

were called for each array presented the subject. The remaining association was recorded because it was the only choice which could have been made. The subjects made their choices while standing. The control knobs were at waist level and the dials were slightly below eye level.

Two students helped make the changes of the dials from one position of the array to another as required. If successive choices had to be made on the same panel during the fifteen test associations, the subject was requested to turn with back toward the panel while the dials were re-arranged.

For Phase Three, each group of fifty subjects made its choices on only one panel position to avoid this evolving a personal pattern of choice when moving the control knobs to another section of the panel.

Phase Five.-- Five students were used as subjects in conducting Phase Five of the study. Each was assigned a number and then the sequence of operator to perform with a knob size arrangement was selected randomly.

Two replications of 45 observations each were taken. Each of the five subjects was required to perform nine different settings on each of three dials, using different size control knobs on each trial.

The "northwest" quadrant, i.e., from seven and one-half to ten on the dials used in this study, has been found to be the preferred section of a dial for making settings or readings (16). The dial settings for the quadrant were drawn from Tippett's Random Sampling Numbers (17). The direction in which the control knob would be turned to make the prescribed setting, i.e., clockwise or counter clockwise, was also selected randomly. Right-handed operation of the control knobs was used.

Numbers for the prescribed dial settings were placed on a panel

which was hinged. The panel, when in the down position, covered the location of the dials. When the person conducting the investigation was ready for the trial to begin, he raised the panel, which exposed the numbers to be set into the dials as well as the dials themselves. Simultaneously with the raising of the panel, a relay was depressed which caused current to energize a solenoid. This solenoid released the brake acting on the left dial and allowed the subject to attempt to make the prescribed setting on that dial.

At the end of two seconds, this solenoid was de-energized by the action of the timer. This action caused the brake to be applied to the pulley associated with the left dial. At the same instant as this occurred, the solenoid containing the brake for the middle dial was energized and allowed the middle control knob and its dial pointer to be rotated. The above action occurred for the operation of the right dial. The sequence of knob operation was from front to back, and the sequence of dial operation from left to right.

The time of two seconds was determined by using reduced predetermined time values so that the subject would be "pressed" to accomplish the task in the time allotted. This time was pre-tested to make sure that the operator could indeed perform the task.

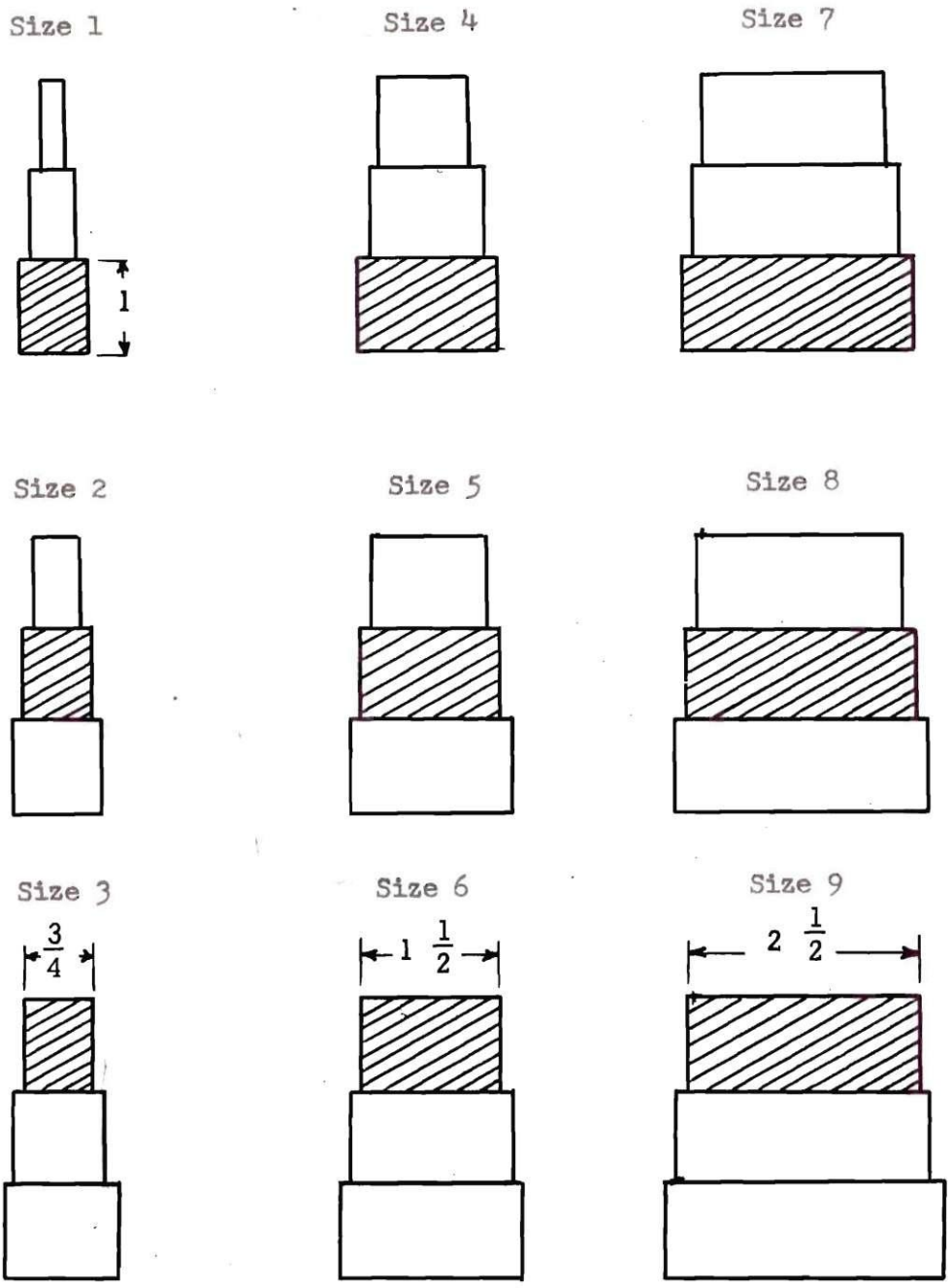
The subject was allowed to place his hand on the front knob before the trial began. When the panel was raised, the signal lamp lit under the left dial, indicating that the dial could be operated. Similar lights came on under the other dials as they could be operated. In addition to the lights, the operator could rely on audible enviromental cues to know what dial could be operated. The energized solenoids did not make the

same noise; thus after a short while, the subjects were able to distinguish them by sound. When the trial began, the lights operated from middle dial to left dial.

Twenty practice trials of settings were allowed each of the five subjects before the start of recording data. Three additional practice trials were given each subject before each day's recorded trials. These practice trials were for the purpose of reducing the error effect of learning between trials and between replications. Operators were seated during the trials and the dials were at, or slightly below, eye level for all the operators.

All distances of pointer travel were held constant during the trials. Three dial divisions or marker intervals in distance from the prescribed setting were pre-set into the dials before the start of the trial. After the subjects made or attempted to make the prescribed settings, the investigator determined if they were within the prescribed accuracy as shown on the back of the panel. He recorded "yes" for a good reading and "no" for a reading outside the tolerance limits.

The knob size arrangements are shown in Fig. 16.



* Cross-hatched dimensions remain constant throughout all size arrangements in vertical column (e.g. Sizes 1, 2, and 3). Other steps are in 1/4 inch diameter changes.

Fig. 16. Knob Size Arrangements Investigated in Phase Five.

CHAPTER IV

ANALYSIS AND DISCUSSION

The chi-square test was used to analyze the results of the first four phases, where associations were measured. This test, in general, is applied to problems for which it is desired to determine whether the frequency of occurrence is significantly different from those which might have been expected under an appropriate null hypothesis. The equation for chi-square is

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Where O is the observed class frequency,

E is the expected class frequency, and

$\sum$ donates summation over all classes.

A correction factor of five-tenths was used in the equation to compensate for discontinuity of the actual distribution (18). This correction factor was added where the observed quantity was less than the expected value and subtracted where it was greater.

If the subjects were not biased in any manner, then the expected class frequency of any knob choice association would be one-sixth of the total preferences measured. This stems from the fact that there were six possible knob arrangements to choose from.

The results of the chi-square tests for shape associations are shown in Table 2. They were all significant at the 0.1 per cent level. This

supports the belief that the choices within any one test were biased to a very high degree by shape association. To substantiate this belief further, a contingency table was prepared to determine if the choices were made independently among the six shape association tests. The significant results are shown in Tables 3 and 4.

Table 2. Results of χ^2 Tests for Shape Association of Dial and Knob. Phase One.

Sequence of Dials	$\Sigma (O-E)^2$	χ^2	d.f.
HRS*	2064.9270	123.8708	5
HSR	3077.4934	184.6126	5
SRH	3839.0334	230.2960	5
RHS	4775.4934	286.4723	5
RSH	4130.1534	247.7596	5
SHR	6153.7470	369.1509	5

*H denotes Hexagonal dial
R denotes Round dial
S denotes Square dial

Table 3. Subject Preference as to Choice of Dial-Knob Association Relating to Shape. Phase One.

Sequence \ Choice	FMB	FBM	MBF	MFB	BFM	BMF	Totals
HRS*	30	1	53	4	2	10	100
HSR	24	1	4	65	0	6	100
SRH	16	72	2	0	0	10	100
RHS	18	1	1	0	1	79	100
RSH	16	1	1	2	75	5	100
SHR	89	1	2	1	1	6	100
Totals	193	77	63	72	79	116	600

* See Table 2.

Table 4. Expected Frequencies for Table 3 on the Assumption of Independence. Phase One.

Choice Sequence	FMB	FBM	MBF	MFB	BFM	BMF	Totals
HRS*	32.167	12.83	10.5	12	13.167	19.33	100
HSR	32. 167	12.83	10.5	12	13.167	19.33	100
SRH	32.167	12.83	10.5	12	13.167	19.33	100
RHS	32.167	12.83	10.5	12	13.167	19.33	100
RSH	32.167	12.83	10.5	12	13.167	19.33	100
SHR	32.167	12.83	10.5	12	13.167	19.33	100
Totals	193	77	63	72	79	116	600

* See Table 2.

The expected values in Table 4 were calculated by taking the total for one row, divided by the total for all cells, and then multiplying this quantity by the total for one column. This gave the expected frequency for one particular association or cell value.

The chi-square test was used as the method of evaluation. The correction factor for continuity was omitted because of the large size of Table 3. For a table with more than two rows of two columns or both, it is generally unnecessary to make a correction (19).

The result of the chi-square test is

$$\chi^2 = 1498.5417,$$

which is significant at the 0.1 per cent level. This indicates that the actual number of subject choices within and among alternative combinations exceeded the expectation, Thus, the null hypothesis of independence within the individual test and among all the tests was rejected.

The results of the chi-square tests, where knob sizes were related to dial sizes, are shown in Table 5. These results are all significant at

the 0.1 per cent level. This indicates that size relationships are the influencing factors in this group of associations.

A contingency table was prepared to test for the independence of choice among the tests of size associations. The results of subjects preferences are shown in Table 6 and the expected frequency on assumption of independence is shown in Table 7.

The results of the chi-square test is

$$\chi^2 = 1556.5375,$$

and is significant at the 0.1 per cent level. The null hypothesis of independence was rejected for the associations used within individual tests and among all of the tests where dial sizes were different.

Table 5. Results of χ^2 Tests for Size Association of Dial and Knob. Phase Two.

Sequence of Dials	$\Sigma (O-E)^2$	χ^2	d.f.
MLS*	2469.9134	148.1651	5
SML	5292.1734	317.4669	5
LSM	3820.1534	229.1633	5
MSL	3449.9134	206.9534	5
SLM	4148.5734	248.8646	5
LMS	4915.9134	294.8958	5

*L denotes large dial.
M denotes medium dial.
S denotes small dial.

Table 6. Subject Preference as to Choice of Dial-Knob Association Relating to Size. Phase Two.

Choice Sequence	FMB	FBM	BMF	BFM	MBF	MFB	Total
MLS*	23	0	14	1	59	3	100
SML		1	10	1	1	1	100
LSM	15	3	5	73	1	3	100
MSL	20	0	6	2	3	69	100
SLM	16	75	4	4	1	0	100
LMS	17	0	80	1	1	1	100
Totals	177	79	119	82	66	77	600

*See Table 5.

Table 7. Expected Frequencies for Table 6 On the Assumption of Independence. Phase Two.

Choice Sequence	FMB	FBM	BMF	BFM	MBF	MFB	Total
MLS*	29.5	13.167	19.83	13.67	11	12.83	100
SML	29.5	13.167	19.83	13.67	11	12.83	100
LSM	29.5	13.167	19.83	13.67	11	12.83	100
MSL	29.5	13.167	19.83	13.67	11	12.83	100
SLM	29.5	13.167	19.83	13.67	11	12.83	100
LMS	29.5	13.167	19.83	13.67	11	12.83	100
Totals	177	79	119	82	66	77	600

*See Table 5.

Phase Three of the investigation was analyzed in the same manner as shape and size associations. The expected frequency was calculated by two methods. Assuming freedom of choice for any of the six possible knob arrangements, the expected value was found to be eight and one-third. Since all possible combinations were not used, the expected value for the various numbers of combinations which were used was calculated for each panel position.

The chi-square test results were found to be significant for all

values at the 0.1 per cent level. These results are shown in Table 8. From the results of the preferences, it can be seen that the stereotype of front-knob-left dial, middle knob-middle dial and back knob - right dial was very predominant. The influence of the stereotype when added to the influence of the staggered panel made the stereotyped choice practically unanimous.

Table 8. Results of the χ^2 Tests for Preference of Dial-Knob Association When Panel is Staggered. Phase Three.

Knob Position	Expected Values	$\Sigma (O-E)^2$	Degrees of Freedom	χ^2
Left Panel	8.33	1203.7534	5	144.5082
Left Panel	16.67	778.7467	2	46.7154
Middle Panel	8.33	1129.6734	5	135.6150
Middle Panel	12.5	913.0000	3	73.0400
Right Panel	8.33	795.0245	5	95.4411
Right Panel	16.67	452.7467	2	27.1593

Considerable differences were observed in arrangements of dials, both in size and shape, that subjects preferred. There were noticeable differences in results of Phase Three when the knobs were moved between the three panels. For this reason, it was deemed advisable to determine whether ranking would be justifiable. The chi-square test was used to analyze the results shown in Table 9.

Table 9. Results of χ^2 Tests to Determine Advisability of Ranking Results. Phases One, Two, and Three.

Association	$\Sigma (O-E)^2$	Expected or Average Frequency	Degrees of Freedom	χ^2
Shape (1st Choice)	758.3353	72.167	5	10.508*
Shape (2nd Choice)	332.8313	18.333	5	18.1547**
Size (1st Choice)	432.8353	73.667	5	5.8755
Size (2nd Choice)	100.3313	15.833	5	5.9604
Staggered Panel (1st Choice)	20.75	37.33	2	.555
Staggered Panel (2nd Choice)	28.75	10	2	2.875
Shape and Size (1st Choice)	1189.2486	72.917	11	16.309
Shape and Size (2nd Choice)	451.0796	17.5833	11	25.6538**

* Indicates significance at 0.10 level.
**Indicates significance at 0.01 level.

This analysis of the feasibility of ranking the choices was made for the shape association alone, for size alone, for staggered panel association alone, and among both shape and size associations combined. The first and second choices of all associations mentioned above were thus analyzed.

The results show only the second choices of associations of shape, and shape and size combined to be significant. The first choice of association of shape alone showed a significance at the 0.10 level which is below the level for accepting or rejecting a hypothesis. It does indicate that further study should be made in this particular phase.

The highest value of any association was when the square dial was on the left, hexagonal dial in the middle, and round dial on the right. This is in the same order as the predominant stereotype. The second highest value of any association was when the small dial was left, medium

dial in middle, and large dial on the right. This is also according to the arrangement of predominant stereotype. These arrays of dials caused the effects of stereotype to be additive to the effects of shape and size associations.

The next largest values of associations were those when the middle dial remained fixed, but the two end dials were reversed from that described above. This is true for both shape and size. The second most common stereotype is that of associating back knob with left dial and progressing outward on the stack until the choice is front knob-right dial. This indicates that if two or more methods of association could be combined into controls, the probability of error would be reduced. People could be so influenced the combination of shape, size, and stereotype that there would be unanimity of choice.

The results which show significance of the second choice of association are of relatively minor importance. The significance can be explained in part by the strong association in two of the six tests, as explained above, and the fact that when both shape and size were tested, the stronger associations were present in four of the twelve tests. The results of the ranking of second highest number of choices are shown in Tables 10 and 11.

Table 10. Ranking of Second Highest Number of Choices Relative to Shape Association (The First Highest Order, i.e., Knob Shape, was not Significant). Phase One.

Rank Order	Sequence of Dials	Second Highest Order of Choice (Position Effect)	Number of Subjects Choosing Association
1	HRS*	FMB**	30
2	HSR	FMB	24
3	RHS	FMB	18
4,5	SRH	FMB	16
4,5	RSH	FMB	16
6	SHR	BMF	6

* Indicates Hexagonal Dial-Left, Round Dial-Middle, Square Dial-Right.
** Indicates Front Knob-Left Dial, Middle Knob-Middle Dial, Back Knob-Right Dial.

Table 11. Ranking of Second Highest Number of Choices Relative to Shape and Size. Phases One an d Two.

Rank Order	Sequence of Dials	Second Highest Order of Choice (Position Effect)	Number of Subjects Choosing Association
1	HRS*	FMB*	30
2	HSR	FMB	24
3	MLS**	FMB	23
4	MSL	FMB	20
5	RHS	FMB	18
6	LMS	FMB	17
7,8,9	SLM	FMB	16
7,8,9	SRH	FMB	16
7,8,9	RSH	FMB	16
10	LSM	FMB	15
11	SML	BMF	10
12	SHR	BMF	6

* See Table 10 for notation.
** Indicates medium size dial-left, large dial - middle, small dial - right.

It is interesting to note that in the shape associations the first five ranks of second highest number of choices is of the predominant stereotype. The sixth rank is of the secondary stereotype, and here the predominant stereotype was coupled with shape association. This furnished further proof that shape and size, individually, are more prevalent in the associations followed in order by the primary and secondary stereotypes. In the ranking among size and shape, the same implications are found. Only the last two in ranked numbers are of the secondary stereotype.

The hypotheses of no significant differences in the number of subjects making a choice between tests are rejected, except in the cases of second choice as related to shape and the second choice among the tests for shape and size combined. Location of control knobs on any one panel section of the staggered panel in phase three was not found to be significant. This applies to both first and second choice. The hypothesis that ranking is in order for the left, middle, or right panel section was rejected. The results of the chi-square test are shown in Table 12.

Table 12. Results of χ^2 Tests to Determine the Advisability of Ranking Knob Position for "Staggered" Panel. Phase Three.

Choice	$\Sigma (O-E)^2$	Expected or Average Value	Degrees of Freedom	χ^2
First	29.416	37.333	2	.787
Second	38.750	10	2	3.875

"Confusion" means the degree of independence for which choices of association are made for any one test. In other words, if there were no

"confusion" among subjects, then all would make the same choice for any one test. The analysis as to whether "confusion" was present within the tests for shape and for size separately, and in the tests for shape and size together was made by using the chi-square test. The significance of the "confusion" factor was also determined for the "staggered" panel array of tests.

The results of the chi-square tests are shown in Table 13.

Table 13. "Confusion" as to Choice of Association Within and Among Various Investigations. Phases One, Two, and Three.

Association	$\Sigma (O-E)^2$	Expected Omissions of Association	Degrees of Freedom	χ^2
Shape	91.5	5	5	18.3**
Size	105.5	5	5	21.1***
Shape and Size	197	5	11	39.4***
Staggered Panel	10.75	5	2	2.15

** denotes significance at 0.01 level.
***denotes significance at 0.001 level.

It is interesting to note from Table 13, the absence of "confusion" in the use of the "staggered" panel array. This is contrasted with the high degree of "confusion" in the shape related phase and the size related phase, as well as when both results were combined.

This rather unusual result of absence of confusion on the staggered panel indicates that the effect of stagger is acting in conjunction with the primary stereotype effect in influencing choice. On the other hand, with the shape and size related phases one and two, the effect of these associations is working against, rather than in conjunction with the pri-

mary stereotype effect except in one presented array for each phase. This further substantiates a prior observation, which in effect says that the best results are achieved when two or more associations can be combined.

The hypotheses of stereotypes for the number of combinations of choices which will be made are accepted for shape alone, size alone, and when the two are combined. The corresponding hypothesis for the staggered panel array is rejected.

Phase Four, dealing with the "V" and inverted "V" array of dials, produced the following results. The stereotype of knob-dial association was followed insofar as the horizontal position was concerned. It can be assumed that with the "V" array, the choices were influenced by counter-clockwise association with respect to dials, as the largest preference of knob choice was front to back. With the inverted "V", a clockwise association was chosen by the largest number of subjects.

The results of the chi-square test are shown in Table 14. Both results were significant at the 0.1 per cent level. Thus, the null hypothesis of independence is rejected and operator bias is significant.

Table 14. Results of Chi-Square Tests for "V" and Inverted "V" Dial Arrays. Phase Four.

Array	$\Sigma (O-E)^2$	Degrees of Freedom	χ^2
Inverted "V"	3746.9294	11	224.7708
"V"	2649.4445	11	158.9348

Analysis of Variance, Phase Five.-- The analysis of Phase Five was performed by using "Analysis of Variance". By proper classification and cross

classification, the total variation of a variable can be divided into meaningful components. The significance of these components can be tested and the relative importance of significant components estimated.

During the original trials of Phase Five, the response of the subject to a given setting was recorded as a "yes" or "no" situation. If the subject's three settings were within the prescribed accuracy limits, three "yes" results were recorded. If a setting or settings were outside the accuracy limits, then a "no" was recorded under the appropriate size(s). These results were later converted to numerical units by arbitrarily assigning a value of one for a "yes" response and a zero for a "no" response (see Tables 15 and 16). The results of each operator's response to a given knob size arrangement were then added to get a total cell value. Thus, the individual cell values could be zero, one, two, or three (see Tables 17 and 18).

The component variables used in the analysis of variance are shown in Table 19, and the results of this analysis are shown in Table 20. Variation in results among knob size arrangements was found to be significant at the one per cent level.

Table 15. Results of Tests for Optimum Accuracy of Varying Size Control Knob Arrangements (First Replication).

Operator	Size 1			Size 2			Size 3			Size 4			Size 5			Size 6			Size 7			Size 8				Size 9		
	¼	½	3/4	½	3/4	1	3/4	1	1¼	1	1¼	1½	1¼	1½	1 3/4	1½	1	3/4	2	2	2¼	2½	2¼	2½	2	3/4	2½	2	3/4	3
1	0	0	0	1	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	1	0			
2	0	0	0	1	1	1	0	0	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1			
3	1	0	0	0	0	0	1	0	0	0	0	1	1	1	0	1	0	0	0	1	1	0	0	0	1	1	1			
4	0	0	0	1	0	1	0	1	0	0	1	1	1	1	0	0	1	0	1	0	1	0	1	1	0	0	1			
5	0	1	0	1	1	1	1	1	0	1	0	0	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1			

Table 16. Results of Tests for Optimum Accuracy of Varying Size Control Knob Arrangements (Second Replication).

Operator	Size 1			Size 2			Size 3			Size 4			Size 5			Size 6			Size 7			Size 8				Size 9		
	¼	½	3/4	½	3/4	1	3/4	1	1¼	1	1¼	1½	1¼	1½	1 3/4	1½	1	3/4	2	2	2¼	2½	2¼	2½	2	3/4	2½	2	3/4	3
1	0	0	0	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	0	1	1	1	1	1	1	0			
2	0	0	1	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	0	1	0	1	1	1	1	0	0			
3	1	0	0	0	1	1	0	1	1	1	1	1	0	1	0	0	0	1	0	0	0	1	0	1	1	0	0			
4	0	0	1	1	1	0	0	1	1	0	1	1	1	0	1	0	0	1	1	0	0	1	0	1	1	1	1			
5	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1			

Table 17. Data and Totals Per Size Arrangement. Results of Tests for Optimum Accuracy of Varying Size Control Knob Arrangements (First Replication).

Accuracy	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8	Size 9
1	0	2	2	3	2	2	1	3	1
2	0	3	1	3	0	2	1	0	2
3	1	0	1	1	2	2	2	0	3
4	0	2	1	2	3	3	2	2	1
5	1	3	2	1	3	2	1	2	2

Table 18. Data Totals Per Size Arrangement. Results of Tests for Optimum Accuracy of Varying Size Control Knob Arrangements. (Second Replication).

Operator	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8	Size 9
1	0	3	3	2	1	2	2	3	2
2	1	1	3	2	2	3	1	3	1
3	1	2	2	3	1	1	0	2	1
4	1	2	2	2	2	1	1	2	3
5	2	3	2	2	3	1	2	3	3

Table 19. Components Variables Used in Analysis of Variance Model for Phase Five.

Factor	Symbol	Model	No. Levels
Replication	R	Fixed	2
Size	S	Fixed	9
Operator	O	Random	5

Table 20. Analysis of Variance for Phase Five.

Source	Sum of Squares	d.f.	Mean Square	F. Ratio
S - Size	17.0223	8	2.1277	3.0742*
O - Operator	5.4000	4	1.3500	1.9505
R - Replication	1.6000	1	1.6000	2.3118
RS	6.8000	8	0.8500	
SO	18.2000	32	0.5687	
RO	.9556	4	0.2389	
ROS	8.7555	16	0.5472	
Residual	17.8889	16	1.1181	
Total	76.6223	89		
Pooled	52.6000	76	.6921	

* Indicates significance at the 0.01 level.

To compute the F Ratio, a mean square of a source is normally divided by the residual mean square. The results of these computations showed no F Ratio to be significant in this analysis. Because of this, the interactions and residual sums of squares were pooled to provide a new estimate of the error. These results showed that the effect of different size arrangements produced the only significant variation. This significance of knob size indicated that one or more of the differences among the means of the dependent variables were significantly related to size but did not identify which ones were significant. To determine which of the knob size differences were significant, Duncan's (20) Multiple Range and Multiple F Tests were used. The results of these tests are shown in Table 21 and show only the difference of the mean of the results from the smallest size knob arrangement to be significantly different from the seven largest mean results. The significance level was one per cent. The two smallest values of the means were not significantly different.

The size of the smallest knob arrangement had a three-fourths inch diameter in the back position, one-half inch in middle position, and one-fourth inch diameter in front position.

Table 21. Worksheet for Multiple Range and Multiple F Tests For Phase Five.

(a) Standard Error of a Size Mean

$$Sm = .6921/10 = .2631$$

(b) Shortest Significant Ranges

p:	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rp:	.9840	1.0261	1.0550	1.0787	1.0918	1.1076	1.1198	1.1287

(c) Results (Means are in ranked order)

Sizes:	(1)	(7)	(3)	(5)	(6)	(9)	(8)	(2)	(4)
Means:	.7	1.3	1.9	1.9	1.9	1.9	20	21	2.1

Note: Any two means not underscored by the same line are significantly different.*

* Significance level at one per cent.

The large number of errors made in settings using the small size control knobs could be attributed to the physical concept that there was not enough area for the fingers to grip the knob firmly and make the required rotation. This would be especially applicable to the smaller knob in the three knob arrangement.

The results of the analysis of variance for the linear component of size are shown in Table 22. The results show the difference of this linear component to be non-significant. Observation of the data indicate a fairly complex - non-trivial function which was not further evaluated.

Table 22. Analysis of Variance for Linear Component of Size. Phase Five.

Source	Sum of Squares	d.f.	Mean Square	F-Ratio
Linear	11.5039	1	11.5039	.5074
Residual	158.7183	7	22.6740	
Total	170.2222	8		

The results of the analysis for Phase Five produced no one best size arrangement for stacked controls. This is contrary to studies which have been conducted to determine the optimum size for a single control knob operating a linear dial. Jenkins and Connor (21) found a two and three-fourths inch diameter knob was significantly superior to smaller sizes for action potential. In the present investigation, only the smallest size knob arrangement was found to be significantly inferior to seven of the larger size arrangements.

CHAPTER V

SUMMARY AND CONCLUSIONS

All phases of the investigation dealing with preferences of associations were analyzed by means of the chi-square test.

Shape and size took precedence over an established stereotype of association. Test statistics for the null hypothesis of no association, using chi-square, proved to be significant at the 0.1 per cent level for both associations. The results of a contingency table prepared to test for independence of all tests associated with shape and with size proved significant at the 0.1 per cent level.

Staggered panel association tended to strengthen the primary stereotype of association because it tended to be additive or influence subjects in that particular direction; it was found to be significant at the 0.1 per cent level.

The "V" and inverted "V" array supported choice which followed the established stereotype insofar as possible. The established preference tended to be counter-clockwise and clockwise, respectively. Both types of arrays showed preferences which were significant at the 0.1 per cent level.

The effect of ranking (within the phase of shape, of size, and among shape and size combined) proved to be significant only so far as second most numerous choices. The second most numerous choice of the six trials of the shape phase and the same choice of the twelve trials of the shape and size phases combined, were ranked. The ranking showed that, although

shape and size were the predominant associations, the established stereotype played an important part. Location of control knobs on the staggered panel array made no significant difference in association.

The amount of confusion caused by the number of combinations of choices among subjects proved to be significant at the 0.1 per cent level. This was true of shape associations as well as size and also when the results were combined. There was no significant indication of confusion on the staggered panel array.

This leads to the conclusion that a combination of two or more associations should be used whenever possible to reduce the number of errors in choosing between a control and the mechanism which it governs.

An analysis of variance was made on the fifth phase of the investigation. This phase was concerned with the selection of the optimum sizes of stacked control knobs.

Size effect was found to be significant at the one per cent level. Using the Multiple Range Test, this effect was further analyzed. It was found that the results from the smallest size arrangement were significantly different from the results of seven larger size arrangements, at the one per cent level. The linear component of the effect of size was not significant.

One interesting observation is the analogy between an operator manipulating objects by hand and a typical work situation where the use of standard elemental time data presumes the complete independence of operator movements. The stereotypes and "confusion" evidenced by this work creates some doubt as to the validity of the above time study assumption.

A comprehensive review of the results of the study is shown in Table 23.

Table 23. Summary of Results

Phase	Aspect Investigated	Results
One (Dial Shape Related to Knob Shape)	1. Associational Preference	1. Shape-significant
	2. Stereotype	2. Second associational preference
	3. Differences in choices between presented arrays	3. First choice - not significant Second choice - significant
	4. "Confusion"	4. Significant
Two (Dial Size Related to Knob Size)	1. Associational Preference	1. Size-significant
	2. Stereotype	2. Second associational preference
	3. Differences in Choice between presented arrays	3. No significance First and Second Choice
	4. "Confusion"	4. Significant
Two and Three	1. Differences in choice between presented arrays	1. Significant - second choice
	2. "Confusion"	2. Significant
Three (Staggered Panel)	1. Stereotype	1. Strengthened
	2. Difference in choice between knob position	2. Not significant
	3. "Confusion"	3. Not significant
Four	1. Associational Preference "V" array	1. Counter-clockwise significant
	2. Associational Preference inverted "V" array	2. Clockwise significant
Five (Optimum Accuracy)	1. Size Effect	1. Significant
	2. Multiple range	2. Small size - seven larger sizes significant differences
	3. Linear Component - Size effect	3. Not significant

CHAPTER VI

RECOMMENDATIONS

Since all associations proved to be significant by use of the chi-square tests, only a few recommendations will be offered. Ranking of the first largest selection according to shape association was significant at only the ten per cent level. This indicates the need for more research in this particular type of association. It is, therefore, recommended that at least the same number of trials as were previously investigated be tested again with new subjects.

A significant amount of confusion was present in all trials associated by shape, by size, and when the results of the two were combined. Since there was not a significant amount of confusion on the staggered panel, it is recommended that two or more associations should be incorporated into the same test or trials to determine if this confusion would be eliminated. Shape and size could both be combined with the primary stereotype association.

Another recommendation is that the order of stagger be reversed on the "staggered" panel. This would determine what effect this particular association played in the preferences of the subjects, by having it in opposite order of the stereotype.

When conducting research on the optimum size arrangements, the investigator should make further tests of the same sizes of knobs as well as for new size arrangements. While the difference in diameters for this

experiment was only one-fourth inch, it is recommended that the diameters be varied by three-eighths and one-half inch differences.

Since the knob lengths were held constant at one inch, it seems desirable to establish the correct or best lengths of the knobs. For varying lengths of knobs, there should be a corresponding optimum arrangement of diameters. A number of these arrangements should be found and incorporated in tabular form as an aid in design work.

Although the effect of friction was considered to have negligible influence on the investigation, still the average gripping power at various distances should be found. As the total length of the knobs are increased, the diameter to be gripped would be decreased for a specific amount of power response needed. Charts and tables have been prepared on human measurements of many forms. Gripping power is included in these but none seem to be related to the power of the average person's hand as distance is varied from palm to object.

A P P E N D I X A

RESULTS OF TESTS FOR PREFERENCES OF ASSOCIATIONS

Table 24. Recorded Preferences of Association When Shape of Dials Related to Shape of Knobs (100 subjects). Phase One.

Investigation Sequence	1			2			5			10			11			14		
Dial Sequence	H	R	S	H	S	R	S	R	H	R	H	S	R	S	H	S	H	R
100	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
99	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
98	B	F	M	F	M	B	B	M	F	F	B	M	F	M	B	M	B	F
97	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
96	B	M	F	F	M	B	F	M	B	B	M	F	B	F	M	F	M	B
95	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
94	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	B	M
93	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
92	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
91	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
90	F	M	B	F	M	B	B	M	F	B	M	F	B	F	M	F	M	B
89	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
88	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
87	M	F	B	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
86	F	M	B	F	M	B	F	B	M	B	M	F	B	F	M	F	M	B
85	M	B	F	F	M	B	F	B	M	B	M	F	B	F	M	F	M	B
84	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F
83	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
82	F	M	B	M	B	F	F	B	M	B	M	F	B	M	F	F	M	B
81	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F
80	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
79	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
78	F	B	M	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
77	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F
76	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
75	B	M	F	B	M	F	B	M	F	B	M	F	B	F	M	F	M	B
74	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B

Investigation Sequence	1			2			5			10			11			14		
Dial Sequence	H	R	S	H	S	R	S	R	H	R	H	S	R	S	H	S	H	R
73	F	M	B	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
72	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
71	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
70	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
69	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
68	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
67	F	M	B	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
66	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
65	F	M	B	F	M	B	F	M	B	B	M	F	B	F	M	F	M	B
64	F	M	B	M	F	B	F	B	M	B	M	F	M	F	B	B	M	F
63	F	M	B	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
62	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
61	F	M	B	F	M	B	F	B	M	B	M	F	B	F	M	F	M	B
60	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
59	F	M	B	F	B	M	F	B	M	F	M	B	F	M	B	F	M	B
58	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F
57	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
56	B	M	F	B	M	F	B	M	F	B	M	F	B	F	M	F	M	B
55	M	F	B	F	M	B	F	B	M	F	M	B	B	F	M	B	F	M
54	M	B	F	M	F	B	F	B	M	F	M	B	B	F	M	F	M	B
53	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
52	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
51	F	M	B	F	M	B	F	B	M	F	M	B	F	B	M	B	M	F
50	F	M	B	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
49	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
48	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
47	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
46	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
45	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B

Investigation Sequence	1			2			5			10			11			14		
Dial Sequence	H	R	S	H	S	R	S	R	H	R	H	S	R	S	H	S	H	R
44	F	M	B	F	M	B	F	B	M	F	M	B	F	M	B	F	M	B
43	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
42	F	M	B	F	M	B	F	B	M	B	M	F	B	F	M	F	M	B
41	B	F	M	M	B	F	F	B	M	B	M	F	B	F	M	F	M	B
40	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
39	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
38	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
37	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
36	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
35	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
34	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
33	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
32	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
31	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
30	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
29	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
28	M	B	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
27	B	M	F	M	F	B	F	B	M	B	M	F	B	F	M	F	M	B
26	F	M	B	M	B	F	B	M	F	B	M	F	B	F	M	F	M	B
25	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
24	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
23	F	M	B	F	M	B	F	M	B	B	M	F	B	M	F	F	M	B
22	F	M	B	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
21	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
20	B	M	F	M	F	B	M	B	F	B	M	F	B	M	F	F	M	B
19	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
18	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
17	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	B	M	F

Investigation Sequence	1			2			5			10			11			14		
Dial Sequence	H	R	S	H	S	R	S	R	H	R	H	S	R	S	H	S	H	R
16	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
15	F	M	B	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
14	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
13	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F
12	M	B	F	M	F	B	F	M	B	F	M	B	F	M	B	F	M	B
11	M	F	B	M	F	B	F	M	B	F	M	B	F	M	B	M	F	B
10	F	M	B	F	M	B	B	M	F	B	F	M	B	F	M	F	M	B
9	F	M	B	F	M	B	F	M	B	F	M	B	B	F	M	F	M	B
8	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
7	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
6	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
5	M	F	B	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
4	B	M	F	F	M	B	F	B	M	B	M	F	B	M	F	F	M	B
3	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B
2	F	M	B	M	F	B	F	M	B	F	M	B	F	M	B	F	M	B
1	M	B	F	M	F	B	F	B	M	B	M	F	B	M	F	F	M	B

Totals shown in Table 3.

Table 25. Recorded Preferences of Association When Size of Dials and Control Knobs Related (100 Subjects). Phase Two.

Investigation Sequence	3				4				6				8				12				15			
Dial Sequence	M	L	S	S	M	L	L	S	M	M	S	L	S	L	M	L	M	S						
Subject																								
100	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
99	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
98	B	M	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
97	M	F	B	B	M	F	F	B	M	M	B	F	B	F	M	F	M	B						
96	F	M	B	B	M	F	F	B	M	M	B	F	F	B	M	B	M	F						
95	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
94	M	B	F	F	M	B	B	F	M	F	M	B	F	B	M	B	M	F						
93	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
92	F	M	B	B	M	F	M	F	B	F	M	B	F	B	M	F	M	B						
91	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
90	F	M	B	M	F	B	B	F	M	M	F	B	F	M	B	B	M	F						
89	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
88	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B						
87	M	B	F	F	M	B	M	F	B	M	F	B	F	B	M	B	M	F						
86	M	B	F	F	M	B	B	F	M	M	F	B	F	M	B	B	M	F						
85	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
84	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F						
83	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B						
82	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
81	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F						
80	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
79	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
78	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
77	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F						
76	B	M	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						
75	B	M	F	B	F	M	B	F	M	B	M	F	F	B	M	B	M	F						
74	B	M	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F						

Investigation Sequence	3				4			6			8			12			15	
Dial Sequence	M	L	S	S	M	L	L	S	M	M	S	L	S	L	M	L	M	S
Subject																		
73	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
72	M	B	F	F	M	B	F	M	B	M	F	B	F	B	M	B	M	F
71	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
70	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
69	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
68	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
67	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
66	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
65	F	M	B	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
64	B	M	F	F	M	B	M	F	B	F	M	B	F	B	M	B	M	F
63	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
62	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
61	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	F	M	B
60	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
59	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B
58	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F
57	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
56	B	M	F	B	M	F	B	M	F	B	M	F	F	B	M	B	M	F
55	B	M	F	F	M	B	B	F	M	B	M	F	B	F	M	B	F	M
54	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
53	B	M	F	F	M	B	B	F	M	F	M	B	F	B	M	B	M	F
52	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
51	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
50	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
49	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
48	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
47	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
46	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F
45	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F

Investigation Sequence	3				4				6				8				12				15	
Dial Sequence	M	L	S	S	M	L	L	S	M	M	S	L	S	L	M	L	M	S				
Subject																						
44	F	B	M	F	M	B	F	M	B	F	M	B	F	B	M	F	M	B				
43	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
42	M	B	F	F	M	B	B	F	M	B	F	M	F	B	M	B	M	F				
41	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
40	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
39	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
38	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
37	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
36	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
35	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
34	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
33	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
32	M	B	F	F	M	B	B	F	M	F	M	B	F	B	M	B	M	F				
31	B	M	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
30	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
29	M	F	B	B	M	F	B	F	M	M	F	B	F	B	M	B	M	F				
28	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
27	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
26	B	M	F	F	B	M	B	M	F	M	F	B	F	B	M	B	M	F				
25	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
24	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
23	F	M	B	F	M	B	F	M	B	F	M	B	F	B	M	B	M	F				
22	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
21	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
20	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
19	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
18	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
17	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
16	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				

Investigation Sequence	3				4				6				8				12				15	
Dial Sequence	M	L	S	S	M	L	L	S	M	M	S	L	S	L	M	L	M	S				
Subject																						
15	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
14	M	B	F	F	M	B	B	F	M	M	F	B	F	M	B	B	M	F				
13	B	M	F	B	M	F	B	M	F	F	M	B	B	M	F	B	M	F				
12	B	M	F	F	M	B	F	M	B	F	M	B	F	B	M	B	M	F				
11	M	B	F	F	M	B	B	F	M	F	M	B	B	F	M	M	F	B				
10	F	M	B	F	M	B	B	F	M	B	F	M	F	M	B	F	M	B				
9	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
8	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
7	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
6	M	F	B	B	M	F	F	B	M	M	B	F	B	F	M	F	M	B				
5	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
4	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				
3	M	B	F	F	M	B	B	F	M	M	F	B	F	M	B	B	M	F				
2	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B	F	M	B				
1	M	B	F	F	M	B	B	F	M	M	F	B	F	B	M	B	M	F				

Totals shown in Table 6.

Table 26. Results of Preferences of Association on "Staggered" Panel Array (50 Subjects at each of three knob Positions). Phase Three.

Investigation Sequence	9				9			
Dial Position	L	M	R		L	M	R	
Knob Position	Middle Panel				Middle Panel			
50	F	M	B		25	B	M	F
49	F	M	B		24	F	M	B
48	B	M	F		23	F	M	B
47	F	M	B		22	F	M	B
46	B	M	F		21	M	F	B
45	F	M	B		20	F	M	B
44	F	M	B		19	F	M	B
43	B	F	M		18	F	M	B
42	F	M	B		17	F	M	B
41	F	M	B		16	F	M	B
40	F	M	B		15	F	M	B
39	F	M	B		14	F	M	B
38	F	M	B		13	F	M	B
37	F	M	B		12	F	M	B
36	F	M	B		11	F	M	B
35	F	M	B		10	F	M	B
34	B	M	F		9	F	M	B
33	F	M	B		8	B	M	F
32	F	M	B		7	F	M	B
31	B	M	F		6	F	M	B
30	F	M	B		5	M	B	F
29	F	M	B		4	F	M	B
28	F	M	B		3	M	F	B
27	B	M	F		2	F	M	B
26	F	M	B		1	F	M	B

Investigation Sequence	9				9		
Dial Position	L	M	R		L	M	R
Knob Position	Right Panel				Right Panel		
50	F	M	B	25	B	M	F
49	F	M	B	24	F	M	B
48	B	M	F	23	F	M	B
47	B	M	F	22	M	F	B
46	F	M	B	21	F	M	B
45	F	M	B	20	F	M	B
44	F	M	B	19	F	M	B
43	F	M	B	18	B	M	F
42	F	M	B	17	F	M	B
41	M	F	B	16	F	M	B
40	B	M	F	15	F	M	B
39	F	M	B	14	B	M	F
38	B	M	F	13	F	M	B
37	B	M	F	12	F	M	B
36	F	M	B	11	F	M	B
35	B	M	F	10	B	M	F
34	B	M	F	9	F	M	B
33	F	M	B	8	F	M	B
32	F	M	B	7	F	M	B
31	F	M	B	6	B	M	F
30	B	M	F	5	F	M	B
29	F	M	B	4	F	M	B
28	B	M	F	3	F	M	B
27	F	M	B	2	F	M	B
26	B	M	F	1	F	M	B

Investigation Sequence	9				9			
Dial Position	L	M	R		L	M	R	
Knob Position	Left Panel				Left Panel			
50	F	M	B		25	F	M	B
49	B	M	F		24	F	M	B
48	F	M	B		23	B	M	F
47	F	M	B		22	F	M	B
46	F	M	B		21	F	M	B
45	F	M	B		20	F	M	B
44	F	M	B		19	F	M	B
43	F	M	B		18	F	M	B
42	F	M	B		17	M	B	F
41	F	M	B		16	F	M	B
40	F	M	B		15	F	M	B
39	F	M	B		14	F	M	B
38	F	M	B		13	B	M	F
37	F	M	B		12	F	M	B
36	M	B	F		11	M	B	F
35	F	M	B		10	F	M	B
34	F	M	B		9	F	M	B
33	F	M	B		8	F	M	B
32	F	M	B		7	F	M	B
31	B	M	F		6	F	M	B
30	F	M	B		5	F	M	B
29	F	M	B		4	B	M	F
28	F	M	B		3	F	M	B
27	B	M	F		2	F	M	B
26	B	M	F		1	F	M	B

Summary

	Right				Middle				Left			
Totals	33	F	M	B	39	F	M	B	40	F	M	B
	15	B	M	F	8	B	M	F	7	B	M	F
	2	M	F	B	2	M	F	B	3	M	B	F
					1	M	B	F				

Table 27. Results of Preferences of Association Associated With "V" and Inverted "V" Arrays. (100 Subjects).

Investigation Sequence	7	13	7	13
Dial Arrays	Inverted "V"	"V"	Inverted "V"	"V"
Subject	Knob Choices	Knob Choices	Subject	Knob Choices	Knob Choices
100	F M B	F M B	61	F M B	F M B
99	F M B	F M B	60	F M B	F M B
98	B M F	F M B	59	F B M	F M B
97	F M B	F M B	58	B M F	B M F
96	B M F	F M B	57	F B M	F B M
95	F M B	F M B	56	F M B	F M B
94	F M B	F M B	55	F M B	F B M
93	F B M	B F M	54	F M B	F M B
92	F M B	F M B	53	F M B	M F B
91	F B M	F M B	52	F M B	F M B
90	F M B	B F M	51	F B M	F M B
89	F M B	F M B	50	M B F	M F B
88	B F M	M F B	49	B M F	B M F
87	M B F	M F B	48	F M B	M B F
86	F M B	F M B	47	F M B	F M B
85	F M B	F M B	46	F B M	F M B
84	B M F	B M F	45	F B M	F B M
83	F M B	F M B	44	F B M	F B M
82	F M B	F M B	43	F M B	F M B
81	B M F	B M F	42	M F B	F M B
80	F M B	F M B	41	F M B	F M B
79	F M B	F M B	40	F M B	F M B
78	F M B	F M B	39	F M B	F M B
77	B M F	F M B	38	F M B	F M B
76	F M B	F M B	37	F M B	F M B
75	B M F	B M F	36	F B M	F B M
74	F M B	F M B	35	F M B	F M B
73	F M B	F M B	34	F M B	F M B
72	F M B	F M B	33	F M B	F M B
71	F B M	F M B	32	F M B	F M B
70	F M B	F M B	31	B M F	B M F
69	F M B	F M B	30	F M B	F M B
68	F M B	F M B	29	F M B	F M B
67	F M B	F M B	28	F M B	F M B
66	F B M	M B F	27	B M F	B M F
65	F M B	F M B	26	M B F	F M B
64	F B M	M F B	25	F M B	F M B
63	F M B	F B M	24	F B M	F B M
62	F M B	F M B	23	F M B	F M B

Investigation Sequence	7	13	7	13
Dial Arrays	Inverted "V"	"V"	Inverted "V"	"V"
Subject	Knob Choices	Knob Choices	Subject	Knob Choices	Knob Choices
22	F M B	F M B			
21	F M B	F M B			
20	F M B	B M F			
19	F M B	F M B			
18	M F B	F M B			
17	B M F	B M F			
16	F M B	F M B			
15	F B M	M F B			
14	F B M	M F B			
13	B F M	B M F			
12	F M B	F M B			
11	B M F	F B M			
10	F M B	F M B			
9	F M B	F M B			
8	F M B	F M B			
7	F M B	F M B			
6	F M B	F M B			
5	F M B	F M B			
4	B M F	F M B			
3	B M F	F M B			
2	F M B	F M B			
1	M F B	F M B			

Summary

73	F	M	B	63	F	M	B
10	B	M	F	14	B	M	F
8	F	B	M	15	F	B	M
5	M	F	B	3	M	B	F
2	M	B	F	3	M	F	B
2	B	F	M	2	B	F	M

A P P E N D I X B

PICTURES OF EXPERIMENTAL APPARATUS

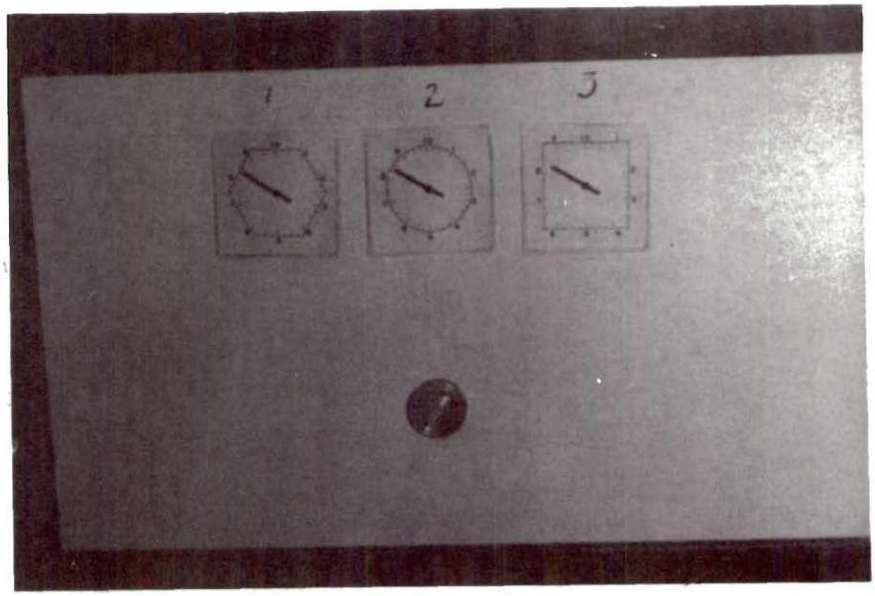


Fig. 17. Array Presented to Subjects. Shape of Dials Related to Shape of Control Knobs.

Fig. 18. "Staggered" Panel Array. Phase Three of Investigation.

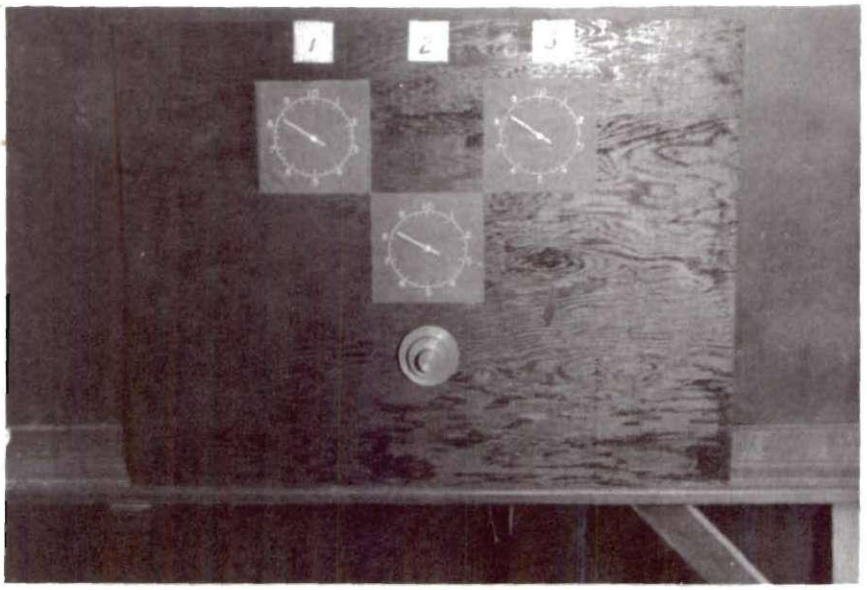


Fig. 19. "V" Shaped Dial Array. Phase Four of Investigation.

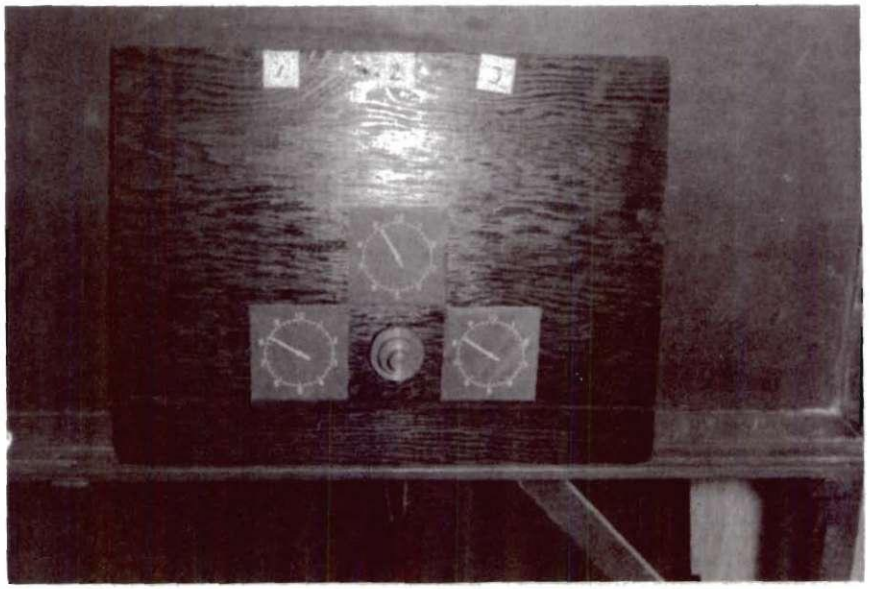


Fig. 20. Inverted "V" Dial Array. Phase Four of Investigation.

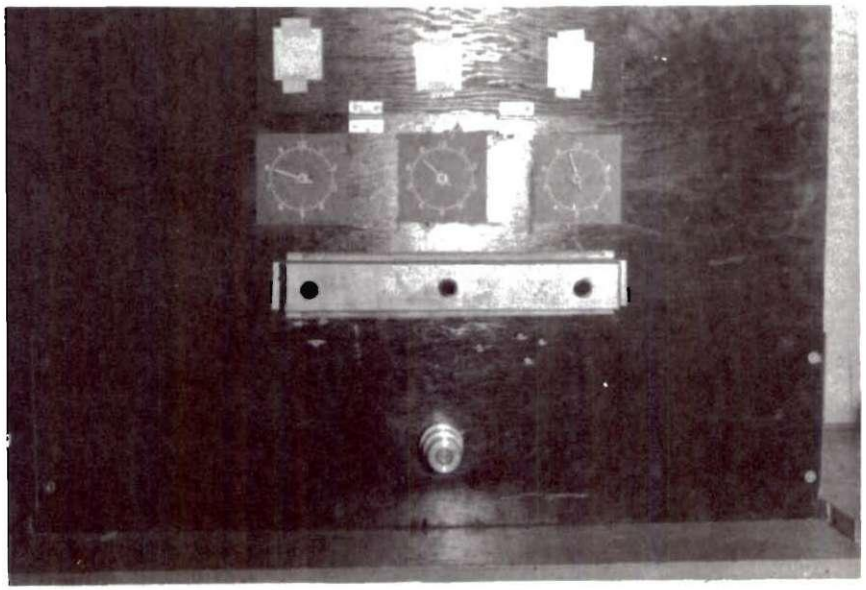


Fig. 21. Front View of Panel Used for Phase Five.

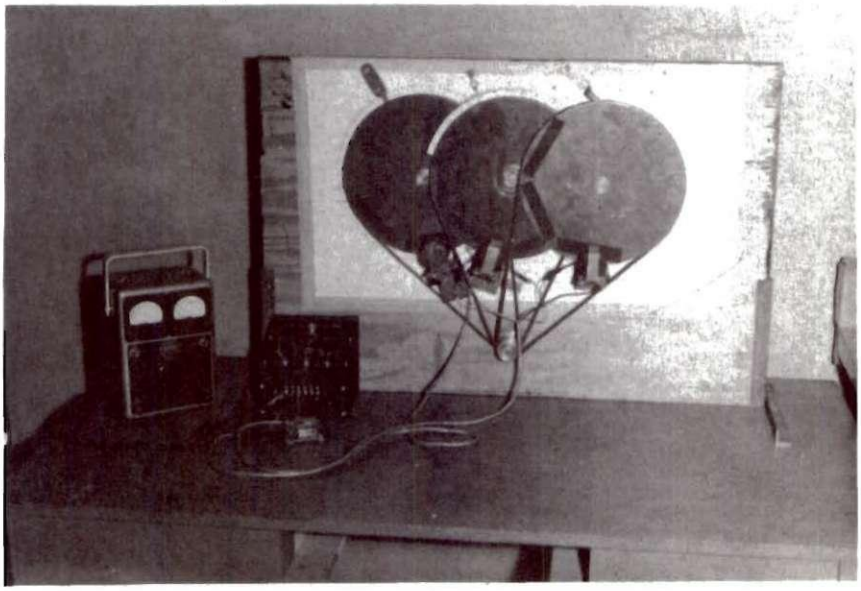


Fig. 22. Rear View of Panel and Instruments Used in Phase Five.

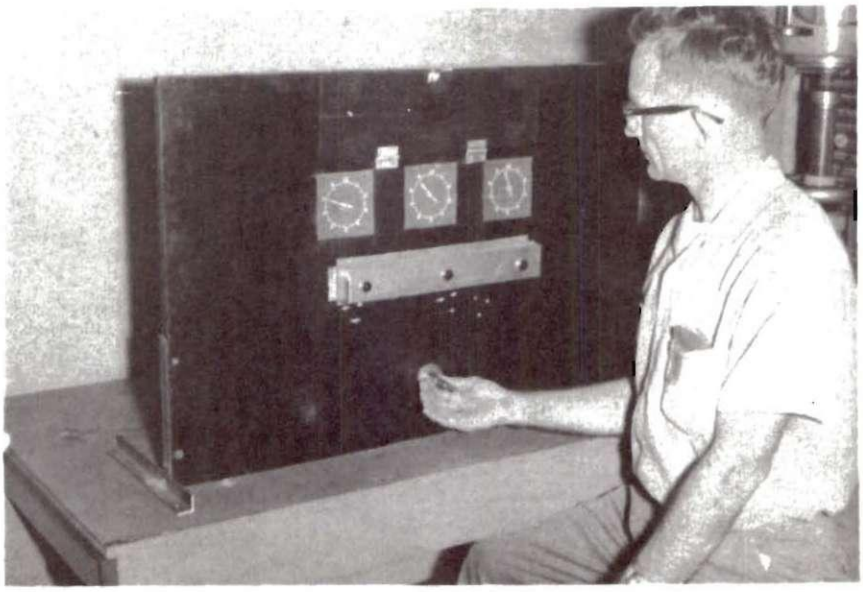


Fig. 23. Small Size Control Knobs Used For Phase Five.

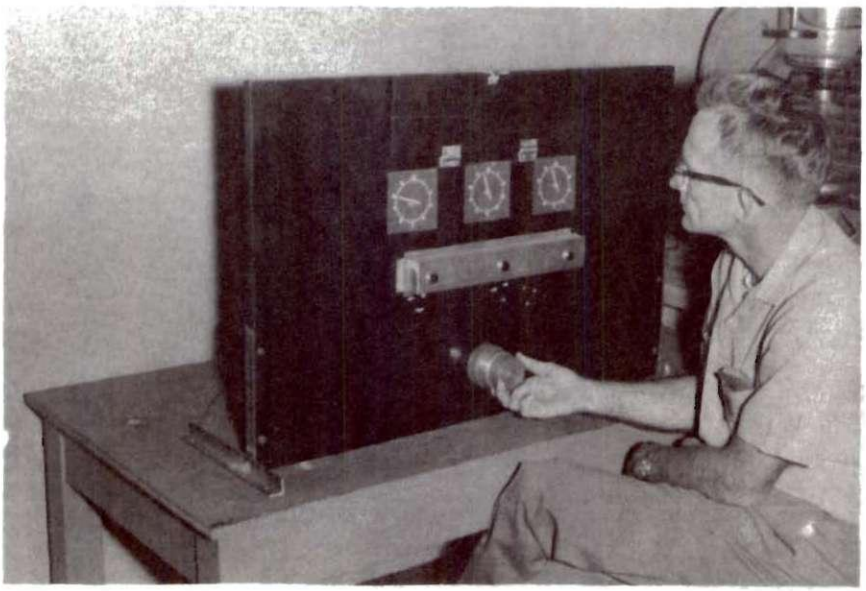


Fig. 24. Largest Size Control Knobs Used for Phase Five.

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